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SPACELAB PHASE B STUDY ENVIRONMENTAL CONTROL SYSTEM COMPONENT HANDBOOK

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Astronautics Laboratory

March 1974

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George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama

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16. ABSTRACT

This document contains descriptions of candidate components for the Phase B Study of the Spacelab Environmental Control System. Most of the hardware was defined for the baseline ECS design concept. A low cost design approach was followed, with most of the components being selected from the Apollo and Skylab Programs.

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TABLE OF CONTENTS

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TABLE OF CONTENTS (Concluded)

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (Continued)

LIST OF ILLUSTRATIONS (Concluded)

LIST OF TABLES

ABBREVIATIONS

ATM	Apollo Telescope Mount
ATP	Acceptance Test Procedure
ECS	Environmental Control System
IU	Instrument Unit
SSP	Space Station Prototype
STP	Standard Temperature and Pressure (0° C and 760 mm Hg)
TCS	Thermal Conditioning System
T_{AI}	Air Inlet Temperature
T_{CI}	Coolant Inlet Temperature
Q_{LAT}	Latent Heat

TECHNICAL MEMORANDUM X-64827

SPACELAB PHASE B STUDY
ENVIRONMENTAL CONTROL SYSTEM COMPONENT HANDBOOK

INTRODUCTION

The purpose of this handbook is to briefly describe candidate Spacelab components as selected for the MSFC Phase B Spacelab Study. With a few exceptions, all the major components are included. This hardware has potential application in the European Spacelab.

Included are hardware photographs and/or cutaway drawings, brief performance specifications, and descriptions of potential problems, design changes, and additional testing required.

The parenthetical data listed with the headings of component descriptions are the component origin. Where component identifications such as "M41" are mentioned, the reader should refer to specific components shown in Figure 1.

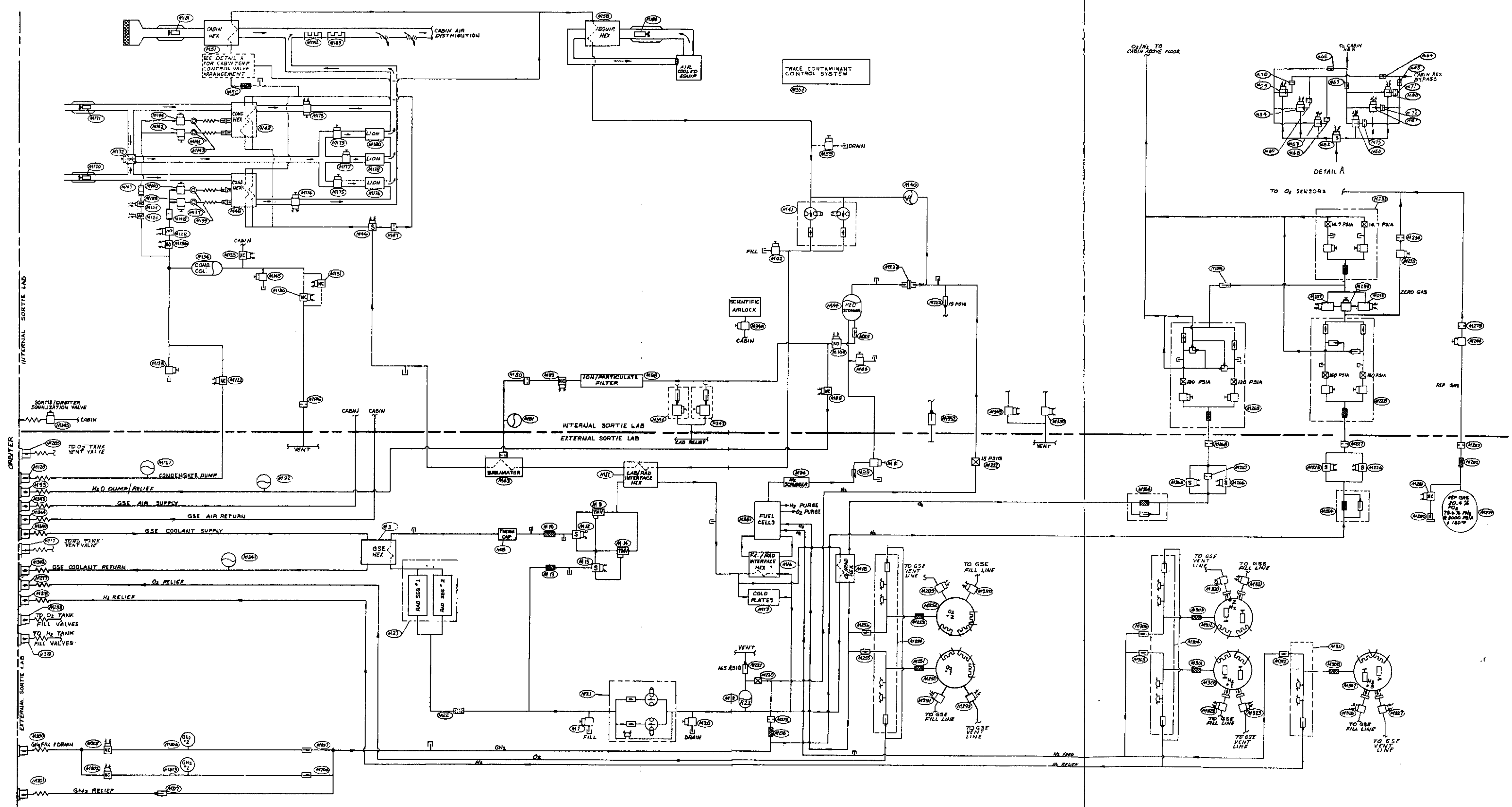

Figure 1. Spacelab ECS mechanical schematic, drawing no. 20M42717.

FOLDOUT FRAME

FOLDOUT FRAME

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CONDENSING HEAT EXCHANGER
(Skylab Program)

Vendor — Airesearch Manufacturing Division of The Garrett Corporation, Los Angeles, California

Vendor P.N.[1] — 640690-3-1

Usability — Selected as baseline design for Spacelab. Performance test and minor requalification required. A disadvantage of this device is the need for flight servicing (plate wetting). (See numbers M48 and M49 on Figure 1.)

DESCRIPTION

The Condensing Heat Exchanger (Fig. 2) used in the Skylab (Airlock) was a modified version used on the Gemini Program. Major modifications made during the Skylab Program on this unit were: (1) the redesign of the water separator assembly permitting inflight replacement without the use of tools, (2) permitting the single water separator assembly to fit on either side of the heat exchanger, and (3) replacement of the refrasil wicking on the water separator plate with a wick of Scott felt open-cell polyurethane foam.

The heat exchanger is a cross counter flow plate fin unit. There are two redundant six-pass coolant circuits and a single-pass gas passage containing wick material to absorb condensed moisture. The wicking material is in parallel layers perpendicular to the gas flow. Each layer is in contact with water separator plate assemblies on either side of the heat exchanger. The plate assemblies consist of fritted glass filters wrapped with polyurethane foam. A wet glass plate has a minimum bubble point of 43.4×10^3 N/m^2. The sandwiches are connected to a low pressure source so that the maximum differential pressure is 34.5×10^3 N/m^2. In this way, water can be condensed and separated from the gas and removed from the heat exchanger. The heat exchanger and water separator plate are shown schematically in Figure 3. Note that in the schematic the mounting of the water separator plate is different than shown in Figure 2 because Figure 3 depicts the flight unit version where Calfax fasteners were used.

1. P.N. is the abbreviation used throughout this document for Part Number.

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Based on the design requirements for humidity control in the Spacelab (Table 1), selection of this Skylab heat exchanger is appropriate.

The design specifications of the Skylab condensing heat exchanger are shown in Table 2 (in this case, oxygen was used as the gas medium). Actual and predicted performance of this unit other than the design point are shown in Figures 4 and 5, respectively.

TABLE 1. SPACELAB DESIGN REQUIREMENTS FOR HUMIDITY CONTROL

Maximum Latent Load (W)	
4 Crewmen in Lab	243.8
$LiOH/CO_2$ Reaction	43.9
Experiments	0
Total	287.7
Nominal Latent Load (W)	
2 Crewmen in Lab	121.9
$LiOH/CO_2$ Reaction	22.0
Experiments	0
Total	143.9
Minimum Latent Load (W)	
1 Crewman in Lab	29.3
$LiOH/CO_2$ Reaction	11.0
Experiments	0
Total	40.3

TABLE 2. SKYLAB CONDENSING HEAT EXCHANGER DESIGN SPECIFICATION SUMMARY

Parameter	Oxygen Side	Coolant Side
Design Flow	4.73×10^{-3} kg/sec entering at 57.2°C and 34.48×10^3 N/m^2 with 49.43 grams H_2O per kg of O_2	10.0×10^{-3} kg/sec at 4.4°C
Condensate Flow	9.83×10^{-5} kg/sec at ΔP = 203.2 mm H_2O	
ATP Flow Rate	$7.48 \times 10^{-3}\ {}^{+\,7.56 \times 10^{-5}}_{-\,0}$ kg/sec air STP	10.0×10^{-3} kg/sec at 4.44°C
Max. Pressure Drop	88.9 mm H_2O (at flow capacity)	2.76×10^3 N/m^2 (at flow capacity)
ATP Pressure Drop	25.4 mm H_2O (at flow capacity)	4.14×10^3 N/m^2 (isothermally at flow capacity)
Max. Operating Pressure	37.92×10^3 N/m^2 gage	827.4×10^3 N/m^2
Proof Pressure	56.88×10^3 N/m^2 gage	13.8×10^5 N/m^2
Burst Pressure	94.8×10^3 N/m^2 gage	20.7×10^5 N/m^2
Operating Temperature Range	4.4 to 48.8°C	-56.6 to +60°C
External Leakage	3.97×10^{-9} kg/sec O_2	0 at 6.895×10^5 N/m^2 gage
Internal Leakage	3.97×10^{-9} kg/sec O_2	0 at 6.895×10^5 N/m^2 gage
Heat Rejection	439.5 W minimum (at flow capacity)	
Service	Gaseous O_2	Coolanol 15
Dry Weight	9.53 kg	
Design Life	2000 hr	
Accumulated Operating Test Time (1 Unit)	4036 hr	
Size	20.8 x 27.9 x 13.4 cm	

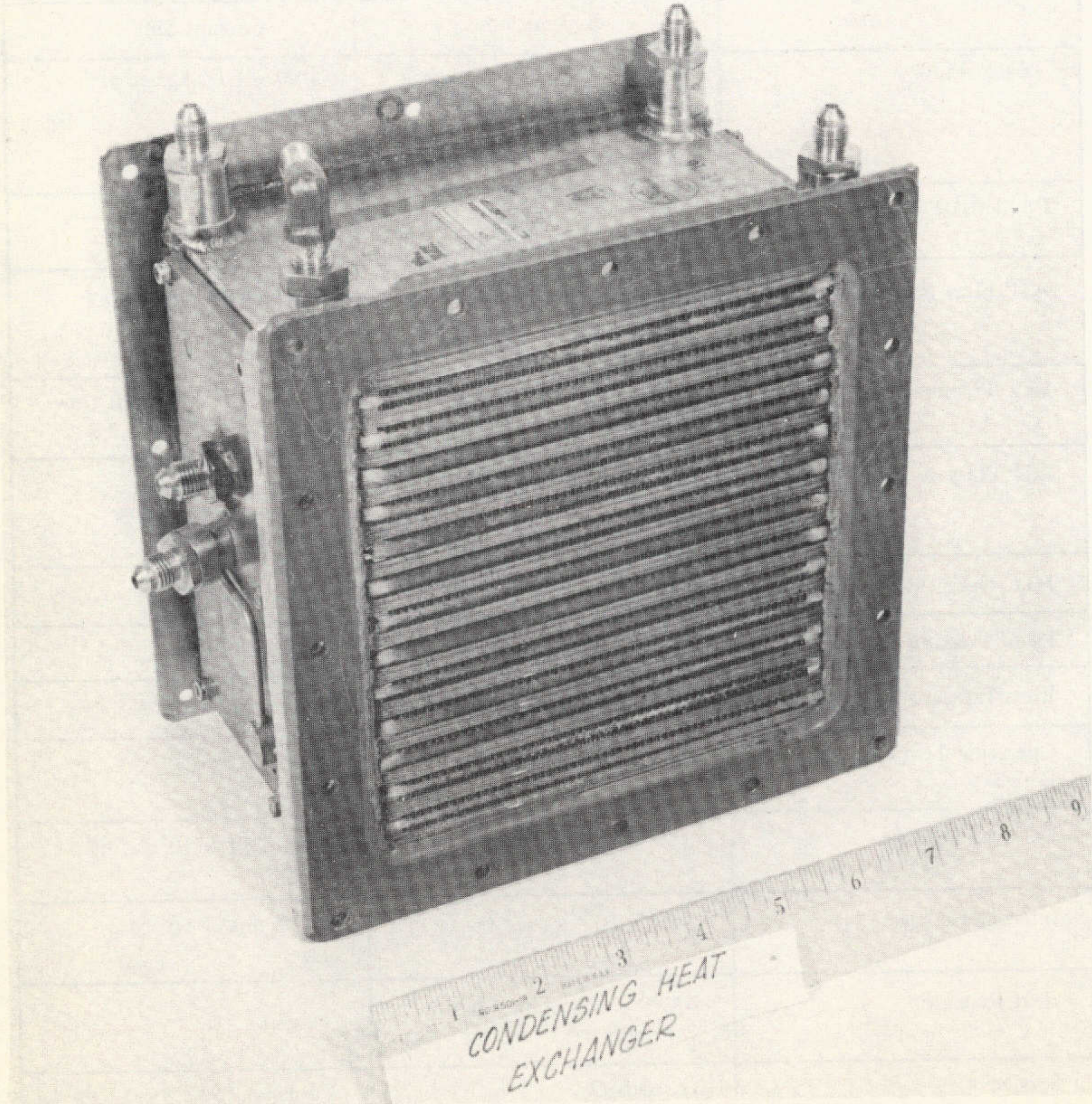

Figure 2. Skylab Condensing Heat Exchanger.

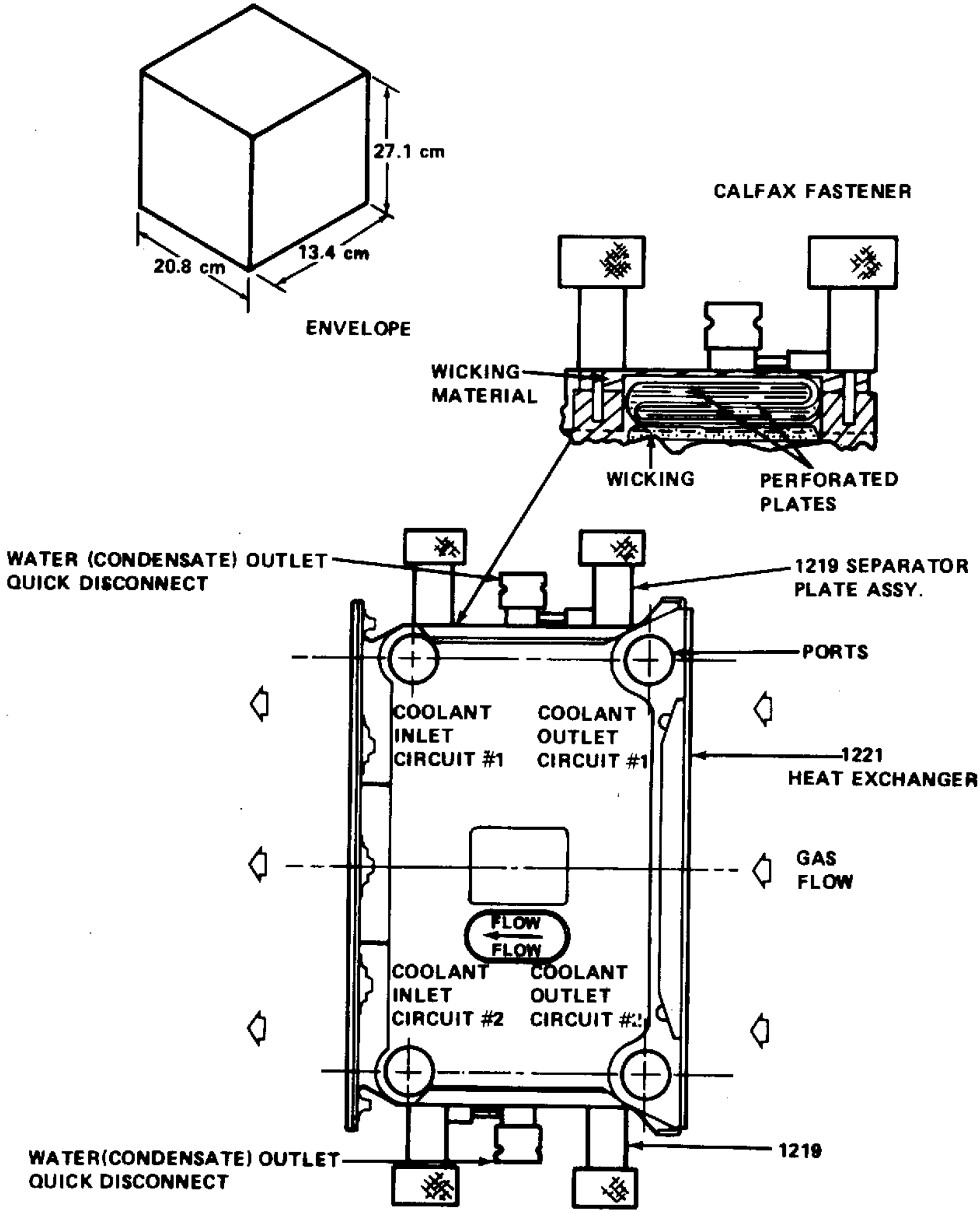

Figure 3. Skylab Condensing Heat Exchanger schematic.

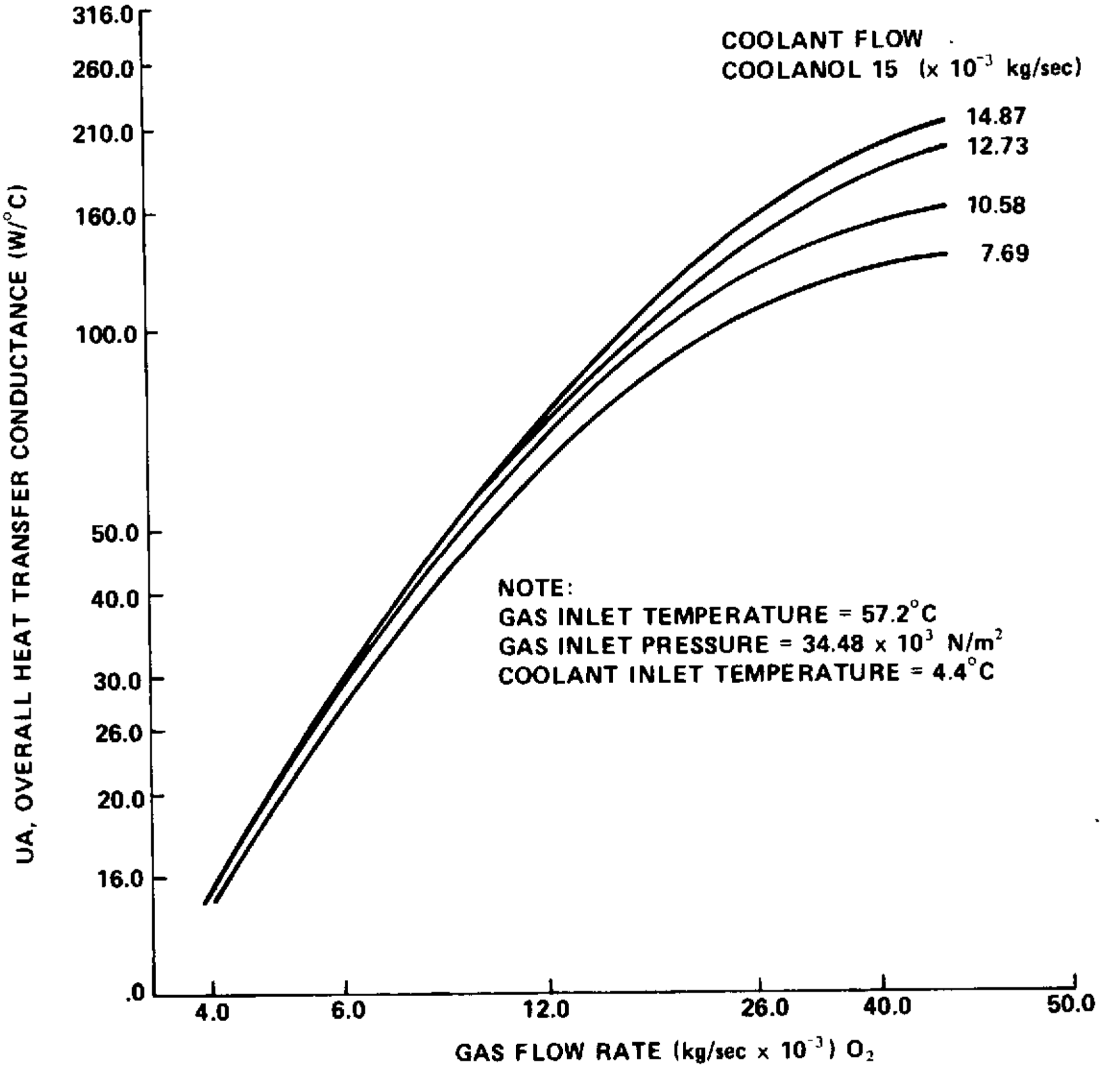

Figure 4. Skylab Condensing Heat Exchanger heat transfer performance. (Curves based on results of Airesearch performance tests.)

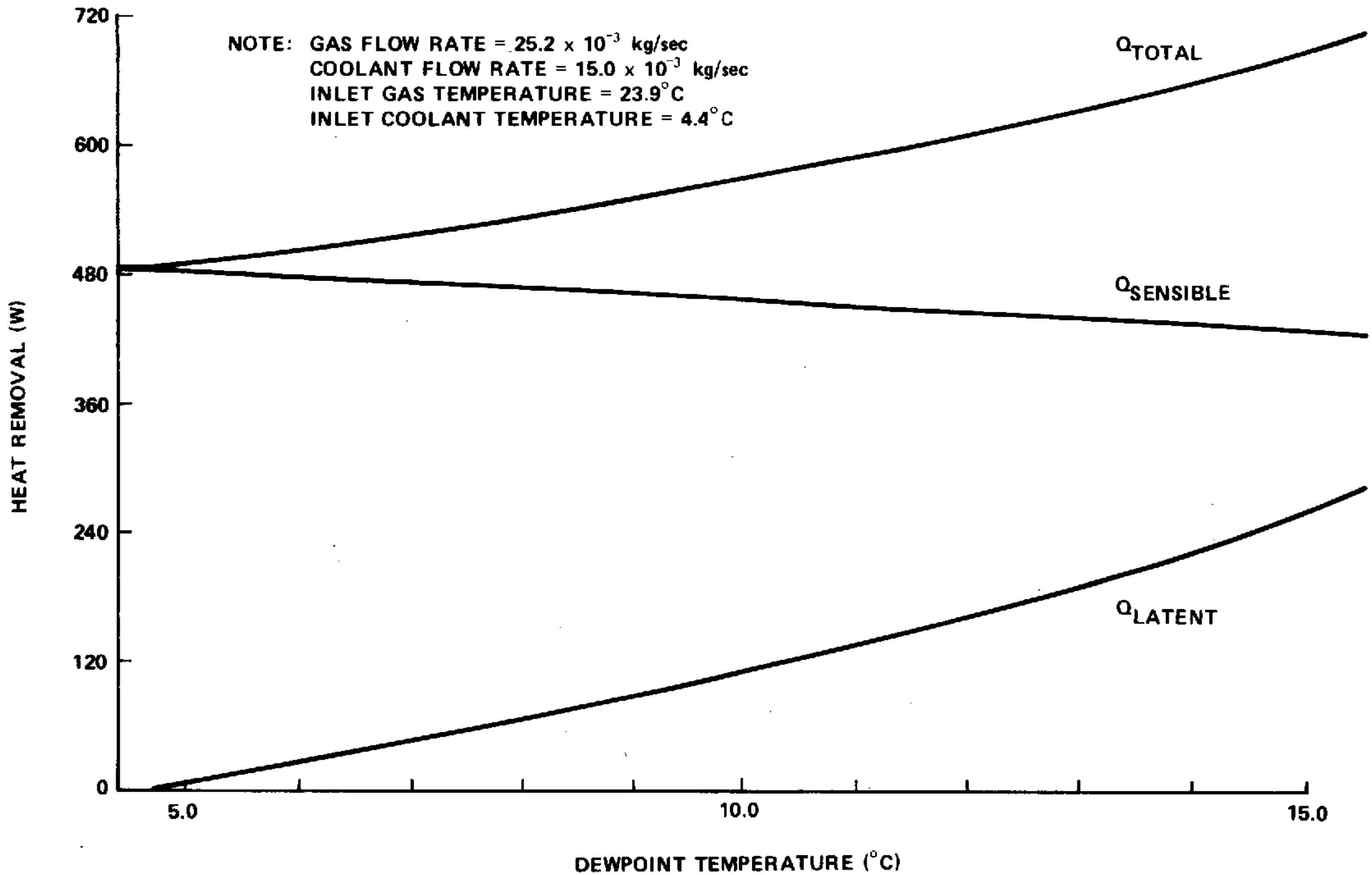

Figure 5. Skylab Condensing Heat Exchanger heat removal using water as the coolant (analytical extrapolation).

SSP HUMIDITY CONTROL ASSEMBLY

Vendor	Hamilton Standard Division of United Aircraft Corporation, Windsor Locks, Connecticut.
Vendor P.N.	Sensible/Condensing Heat Exchanger — SVSK 88394 Water Separator — SVSK 88394 Fan, Centrifugal — SVSK 88393
Usability	Development/qualification test required. A heat exchanger that is similar but smaller in core size is proposed for the Shuttle orbiter. The vortex water separator and fan are common to Shuttle orbiter design. This assembly was not selected for baseline; however, if development tests were successfully performed, baseline would be modified to include it.

DESCRIPTION

The SSP Humidity Control Assembly (Fig. 6) is a prime candidate for the Spacelab and orbiter. It was not identified as baseline due to lack of test data defining performance.

The heat exchanger (Fig. 7) is a tube-fin design. Aluminum fins are used with aluminum-clad stainless coolant tubes. Moisture contained on the fin surfaces is drawn into perforated tubes located at the air outlet face of the unit. Air suction within this tube is provided by the centrifugal fan (see Figure 6). The anticipated suction air flow is between 7.08 and 11.8 l/sec. Fan performance with various orifices is shown in Figure 8. The fan is driven by a three-phase ac motor requiring 200 Vac and 400 Hz; nominal power is 170 watts.

The concentrated water/air mixture extracted from the heat exchanger is drawn into a vortex separator from which the water is removed. The air flow via the fan is returned to the heat exchanger outlet flow stream. The predicted performance of this relative humidity heat exchanger is shown in Figures 9 and 10 for water coolant inlet temperatures of 4.4 and 7.2°C, respectively.

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Limited testing has been performed with the following performance demonstrated:

- Heat Removal = 2812.8 W of which 471.73 W were latent.
- Test Conditions
  - Air Side: Flow = 104.78 l/sec; temperature = 24.7°C dry bulb; dew point = 9.67°C; pressure = 101.36×10^3 N/m^2.
  - Coolant Side: Water flow = 63.0×10^{-3} kg/sec; inlet temperature = 4.11°C; outlet temperature = 6.64°C.

Predicted performance for varying air flow and two given water coolant inlet temperatures is shown.

Dry weight of the hardware is as follows: heat exchanger, 24.49 kg; water separator, 4.54 kg; and fan 2.27 kg.

Test data for the pressure drop across the heat exchanger is given below:

Gas Side (Density of gas = 1.185 kg/m^3)

Gas Flowrate (l/sec)	Pressure Drop - ΔP (mm of H_2O)	
	Dry Core	Wet Core
104	-	7.6
184	-	19.6
236	20.3	25.1

Liquid Side (coolant = water)

Coolant Flowrate[2] (kg/hr)	Pressure Drop (N/m^2)
50.8	689
101.6	1 378
152.4	2 068
203.2	3 447
256.3	4 826
319.8	7 584
635.0	24 132

2. Coolant flow rate through a single coolant passage. Heat exchanger is constructed with two coolant passes.

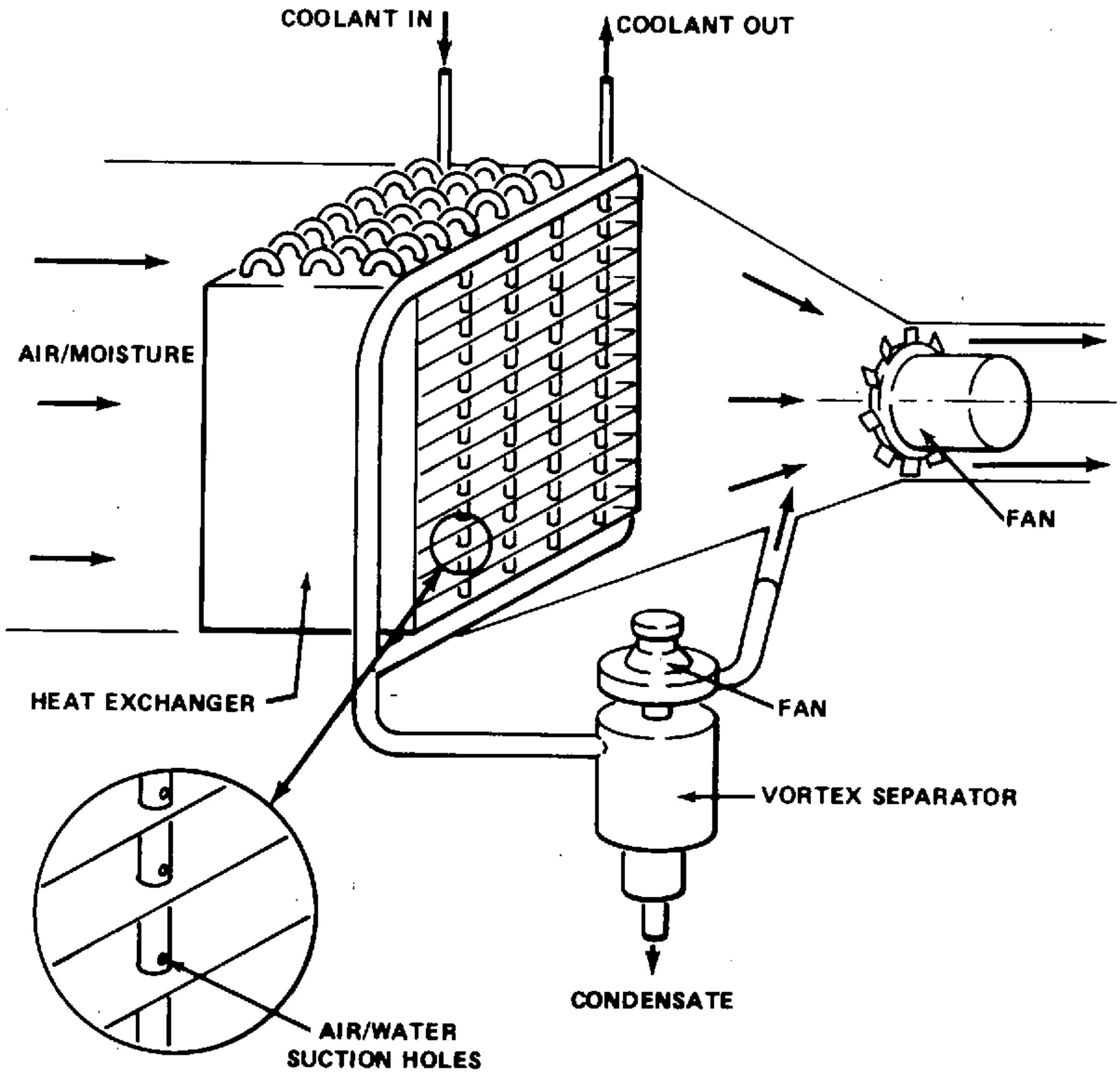

Figure 6. Space Station Prototype Humidity Control System.

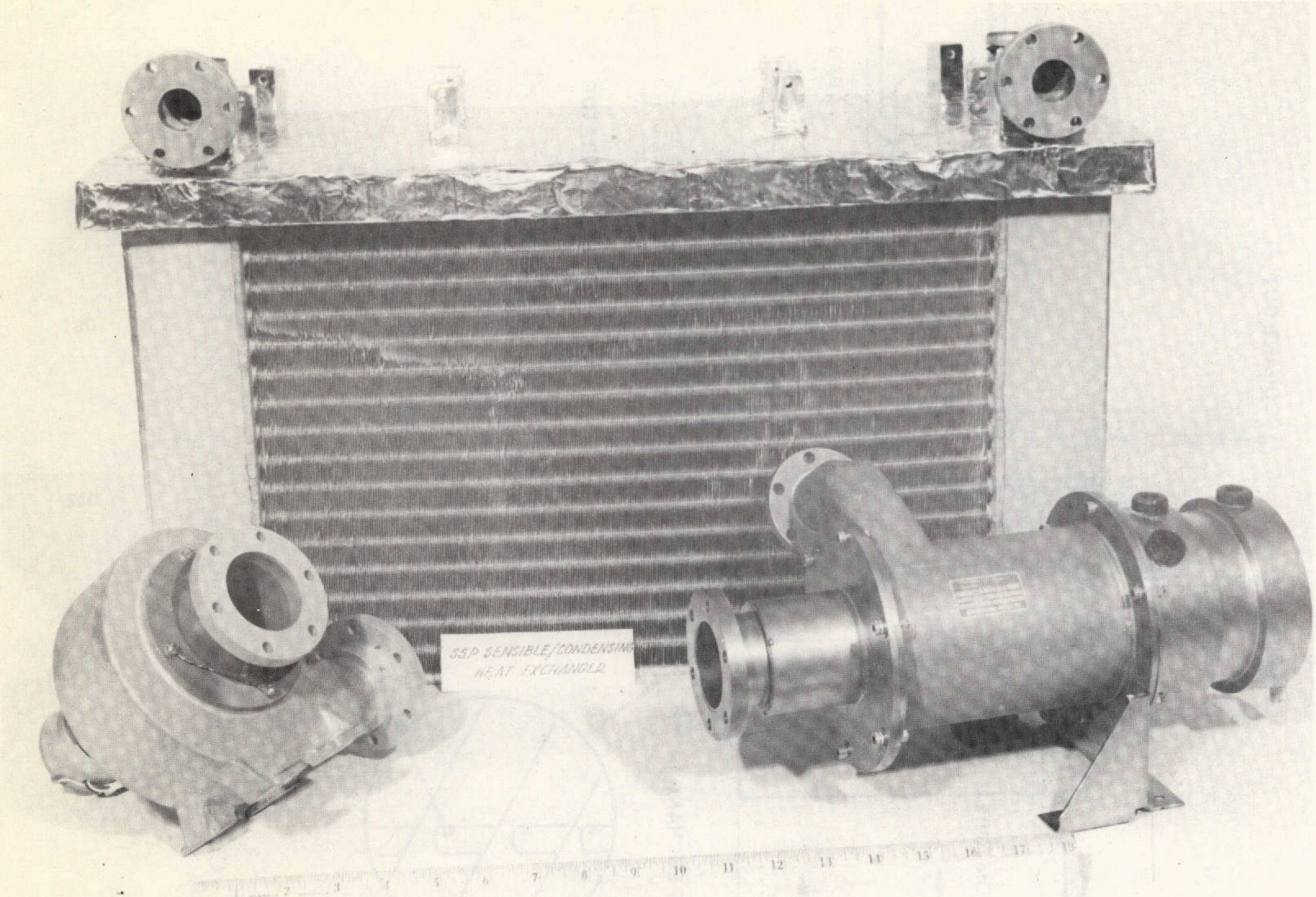

Figure 7. Space Station Prototype sensible/condensing heat exchanger.

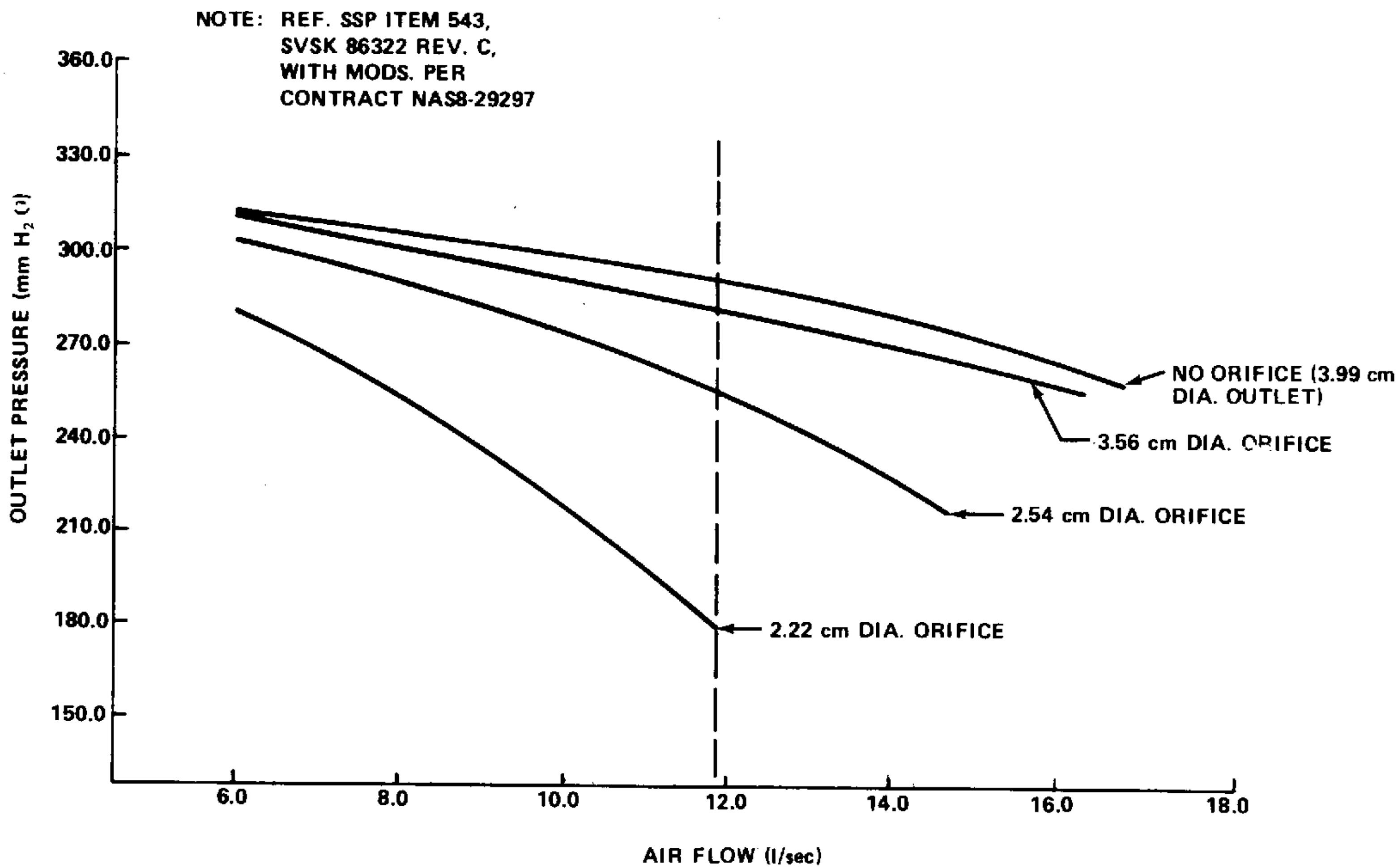

Figure 8. Space Station Prototype vortex air/moisture separator fan performance (air temperature = 21.1°C).

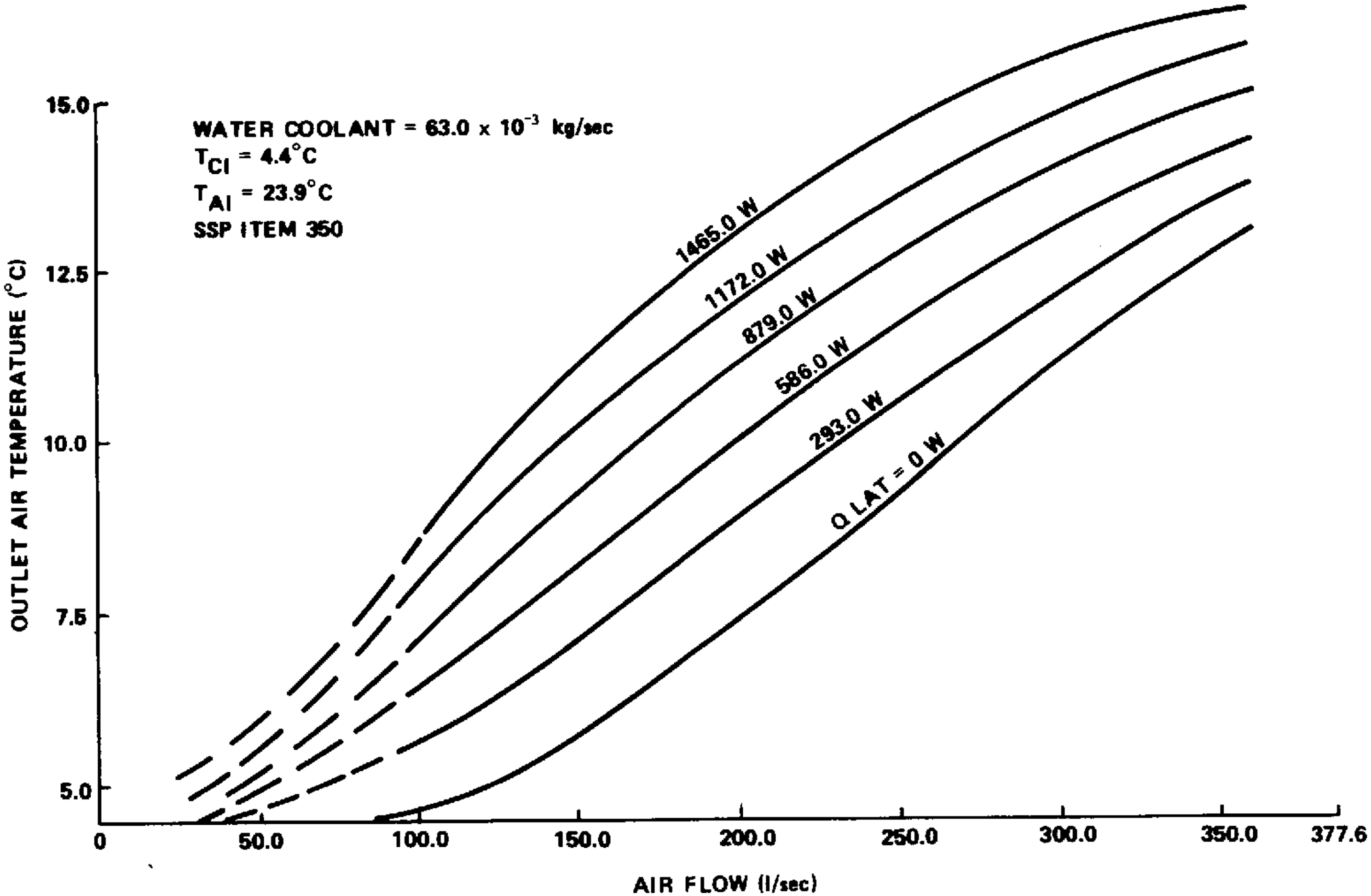

Figure 9. Space Station Prototype relative humidity heat exchanger's performance, water coolant inlet temperature = 4.4°C.

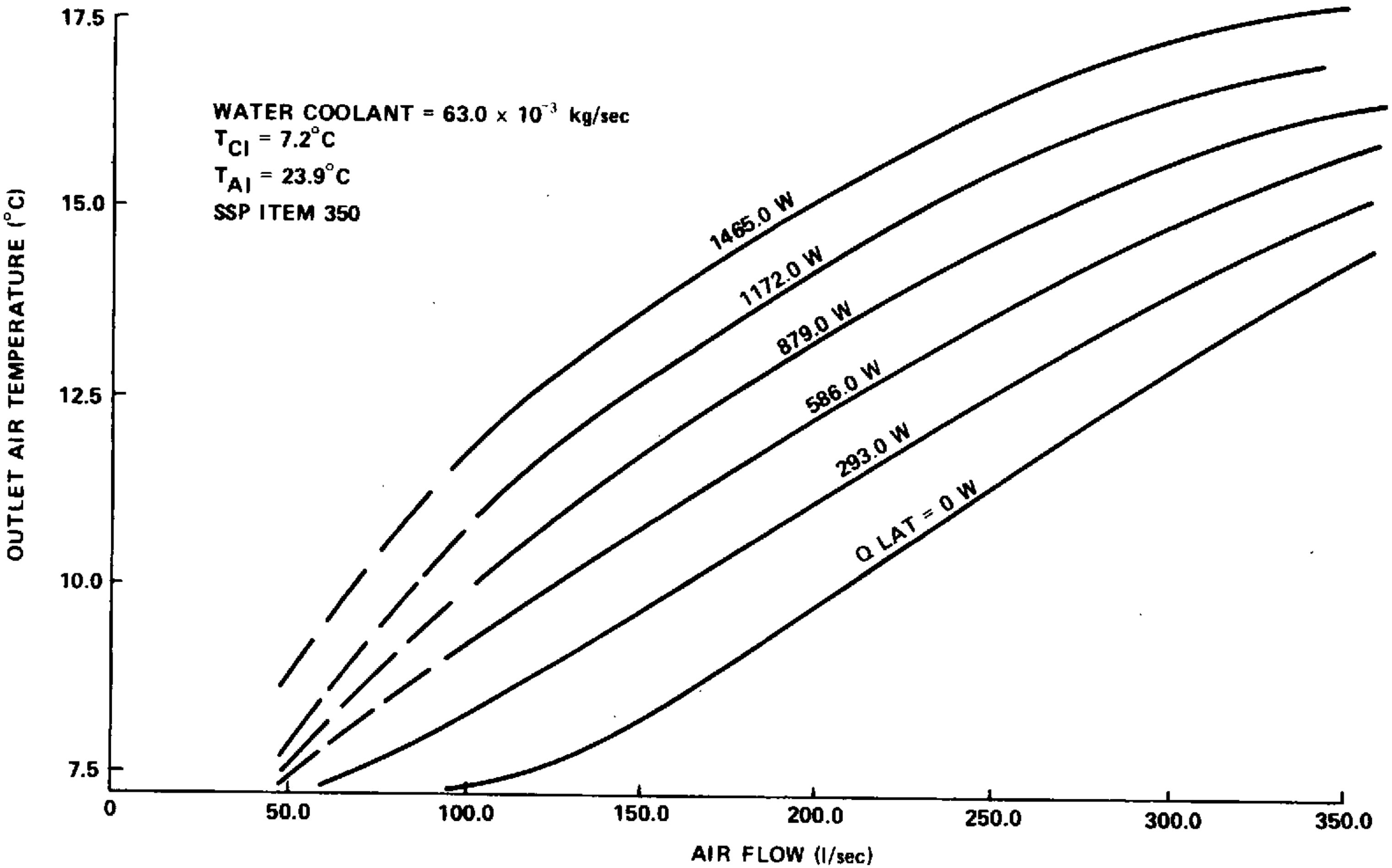

Figure 10. Space Station Prototype relative humidity heat exchanger's performance, water coolant inlet temperature = 7.2°C.

CONDENSATE COLLECTION TANK
(Saturn/Apollo Program-IU)

Vendor	Hamilton Standard Division of United Aircraft Corporation, Windsor Locks, Connecticut
Vendor P.N.	SV 714210-1
Usability	Additional qualification test required for collapsing pressures; no problems anticipated. (See number M84 in Figure 1.)

DESCRIPTION

The tank shown in Figure 11 was selected for the baseline. It was originally used to store distilled water to be used as a sublimate for the IU sublimator. As shown in Figure 12, the tank has two separable halves and a replaceable bladder installed at the plane of separation. The dry weight of the tank is 14.52 kg. The orifice regulator shown in Figure 12 is not required. The original IU application design requirements are compared to the Phase B baseline application in Table 3.

TABLE 3. COMPARISON OF ORIGINAL (IU) AND SPACELAB DESIGN REQUIREMENTS FOR THE CONDENSATE COLLECTION TANK

Parameter	Original Application	Spacelab Application
Medium		
Liquid	Distilled water	Condensate water with absorbed gases and other chemicals
Gas	Dry nitrogen	Spacelab cabin air
Pressure	2.41×10^4 to 4.137×10^4 N/m^2 inside above outside operating; 5.17×10^4 N/m^2 inside above outside proof; 8.62×10^4 N/m^2 inside above outside burst	2.07×10^4 to 3.45×10^4 N/m^2 inside below outside operating
Capacity	66.68 kg of water	66.68 kg of condensate

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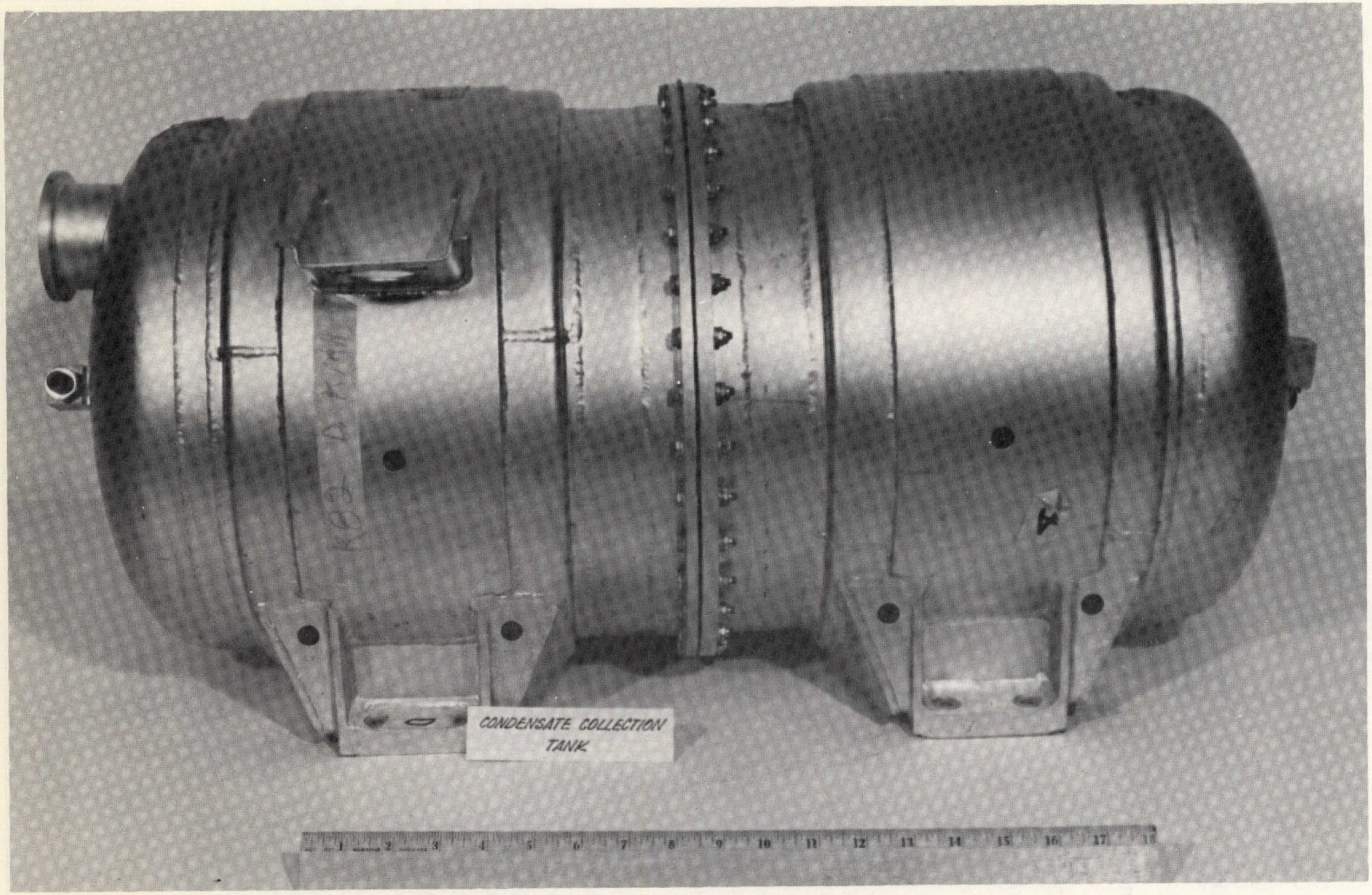

Figure 11. Condensate Collection Tank.

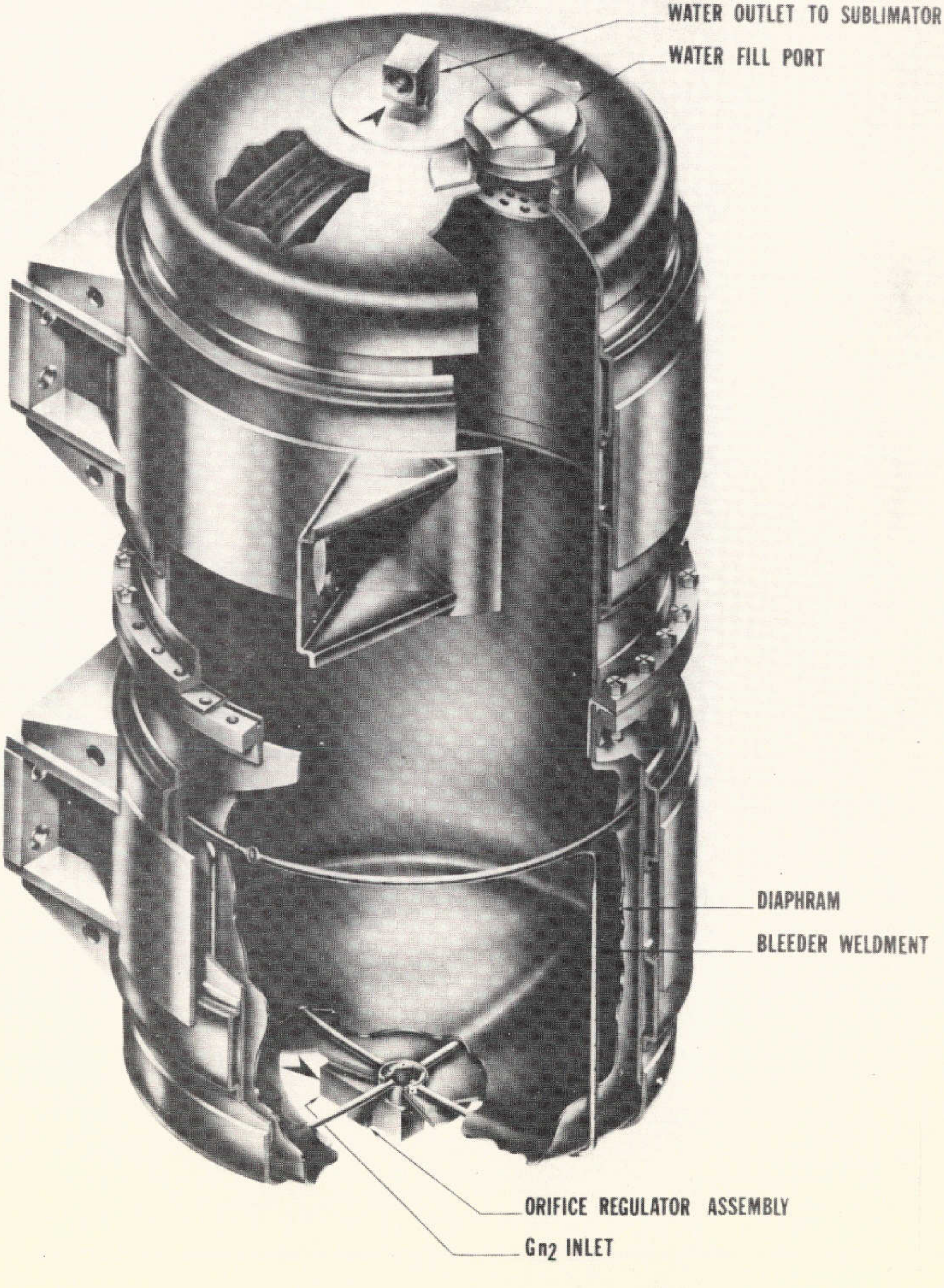

Figure 12. Cutaway view of Condensate Collection Tank (Saturn IB and IU environmental control system's water accumulator).

CABIN/EQUIPMENT LOOP HEAT EXCHANGER
(Skylab Program)

Vendor	Airesearch Manufacturing Division of The Garrett Corporation, Los Angeles, California
Vendor P.N.	167426
Usability	Redesign of the air side transition and elimination of fan are required. Performance test and minor requalification required. (See numbers M51 and M58 in Figure 1.)

DESCRIPTION

The unit shown in Figure 13 was selected for the baseline design. It is a cross-flow, gas-to-liquid heat exchanger with plate/fin construction. Coolant passages are CRES 347 steel. The figure shows assembly of heat exchanger, transition section, and ac motor driven fan (fan is at bottom of picture).

The original Skylab design requirements are compared to the Phase B baseline application in Table 4. For the latter application, performance of the heat exchanger was determined analytically. A lower flow capacity fan, in lieu of the one shown, is required for the Spacelab. Dry weight of the unit is 38.56 kg of which 17.24 kg is the dry weight of heat exchanger.

Gas pressure drop across the heat exchanger for varying flow rates is shown in Figure 14. Analytically derived heat removal versus water coolant flow rate is shown in Figure 15.

TABLE 4. COMPARISON OF ORIGINAL (SKYLAB) AND SPACELAB DESIGN REQUIREMENTS FOR THE CABIN/EQUIPMENT LOOP HEAT EXCHANGER

Parameter	Original Application	Spacelab Application
Medium Gas Liquid	 GN_2 60/40 ethylene glycol/water	 Air Water
Pressure	1.379×10^6 N/m^2 gage operating liquid 2.89×10^6 N/m^2 proof liquid 5.65×10^6 N/m^2 burst liquid 1.01×10^5 to 1.79×10^5 N/m^2 abs. operating gas	3.45×10^5 N/m^2 gage operating liquid 1.01×10^5 N/m^2 abs. gas
Flow and ΔP for Liquid	0.189 l/sec of glycol/water at 6.895×10^4 N/m^2 max with -17.8°C inlet liquid temperature	63×10^3 kg/sec water, ΔP will be small at ≈ 4.4°C water inlet temperature for M51 and ≈ 12.8°C water inlet temperature for M58
Flow and ΔP for Gas	755.2 l/sec of GN_2 at 1.01×10^5 N/m^2 with ΔP across assembly of 43.18 mm of water; assembly includes a fan and motor	264.32 l/sec air for M51 and 330.4 l/sec air for M58; fan and motor will not be used
Temperature	From -28.9 to +37.8°C liquid; from 4.44 to 26.7°C gas	From 4.4 to ≈ 37.8°C liquid; from 4.4 to 43.3°C gas
Heat Capacity	8.2 kW thermal max at 1.01×10^5 N/m^2	2 to 3 kW thermal for M51, 4 to 5 kW thermal for M58

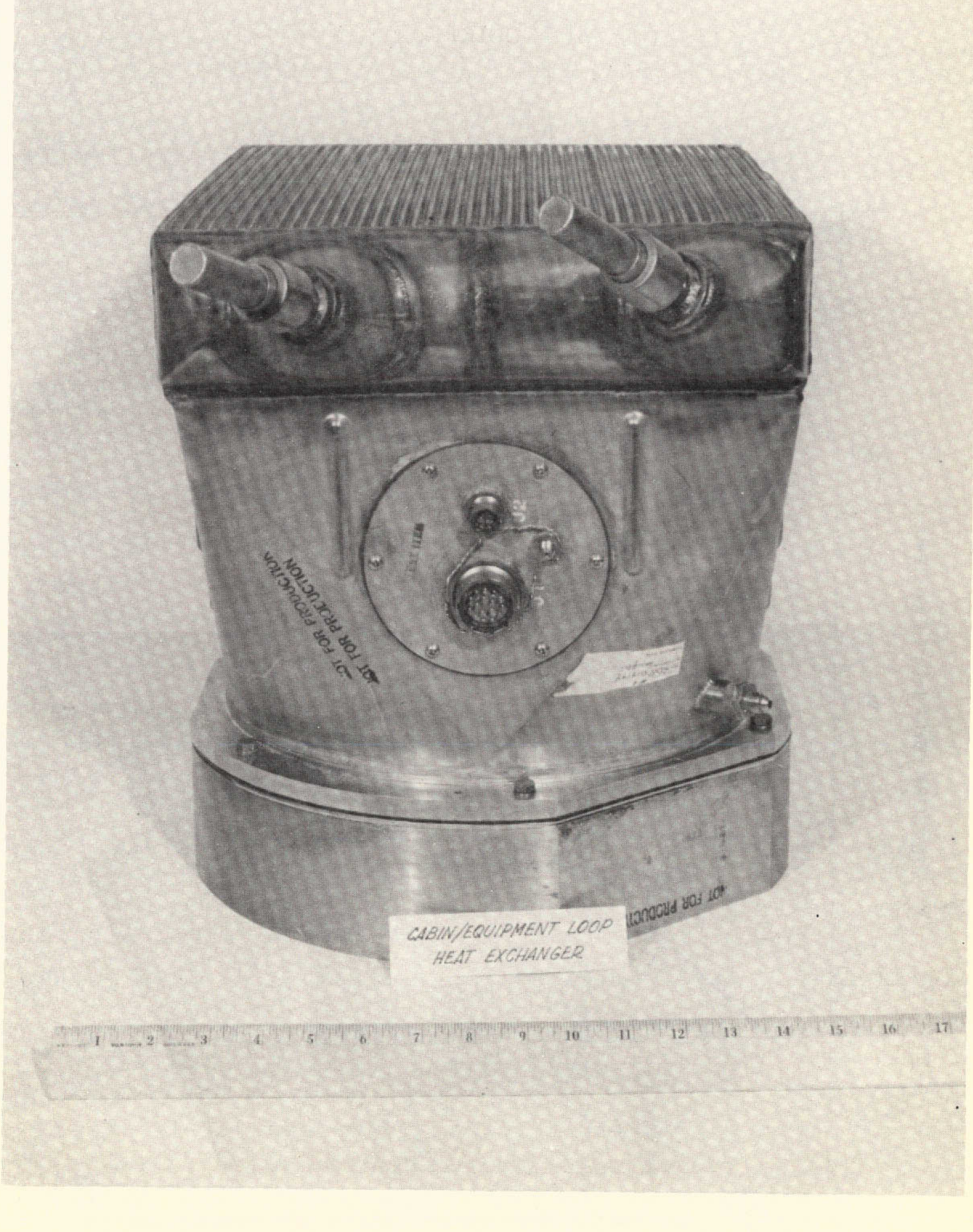

Figure 13. Cabin/Equipment Loop Sensible Heat Exchanger.

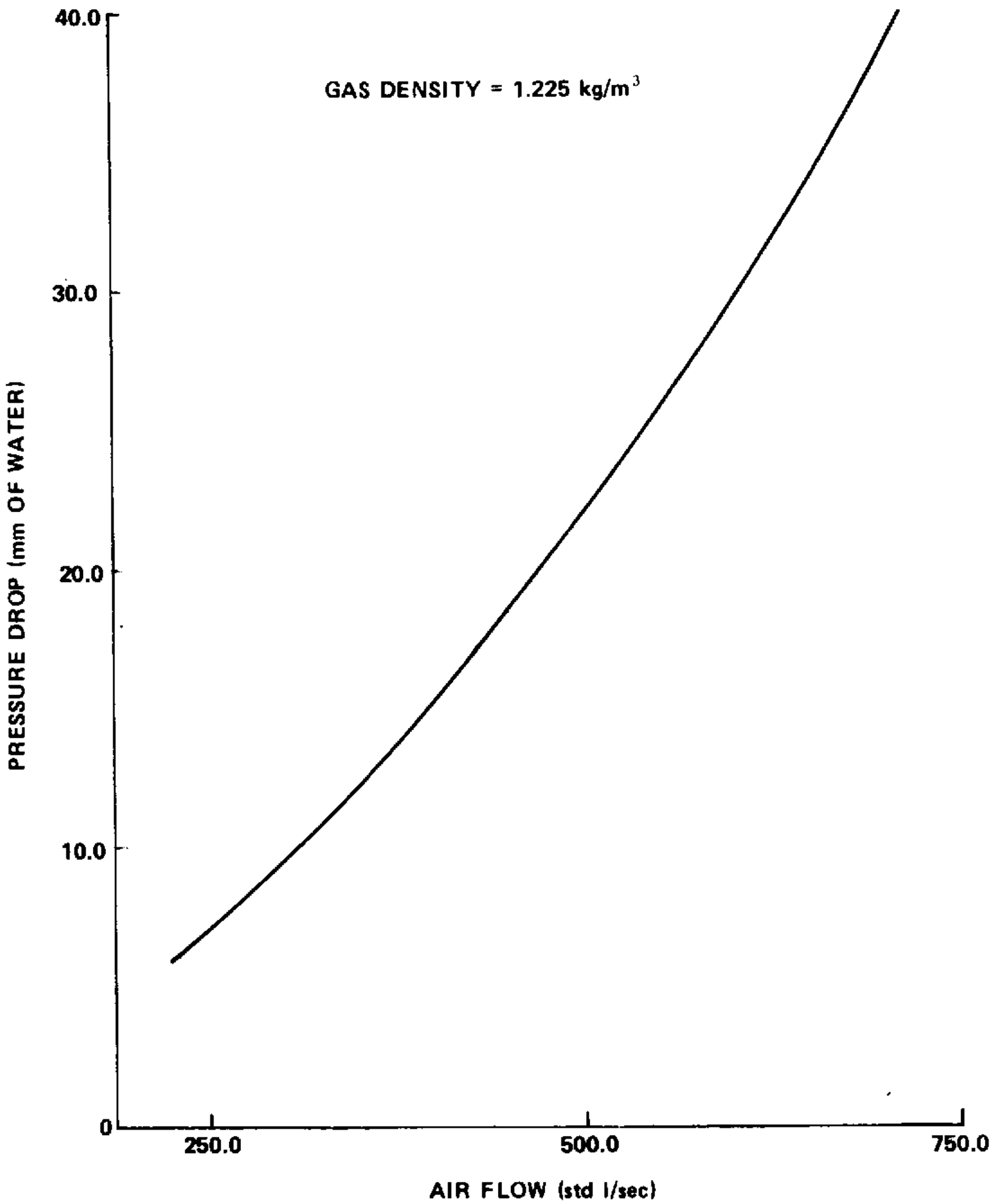

Figure 14. Cabin/Equipment Heat Exchanger pressure drop across the gas medium side.

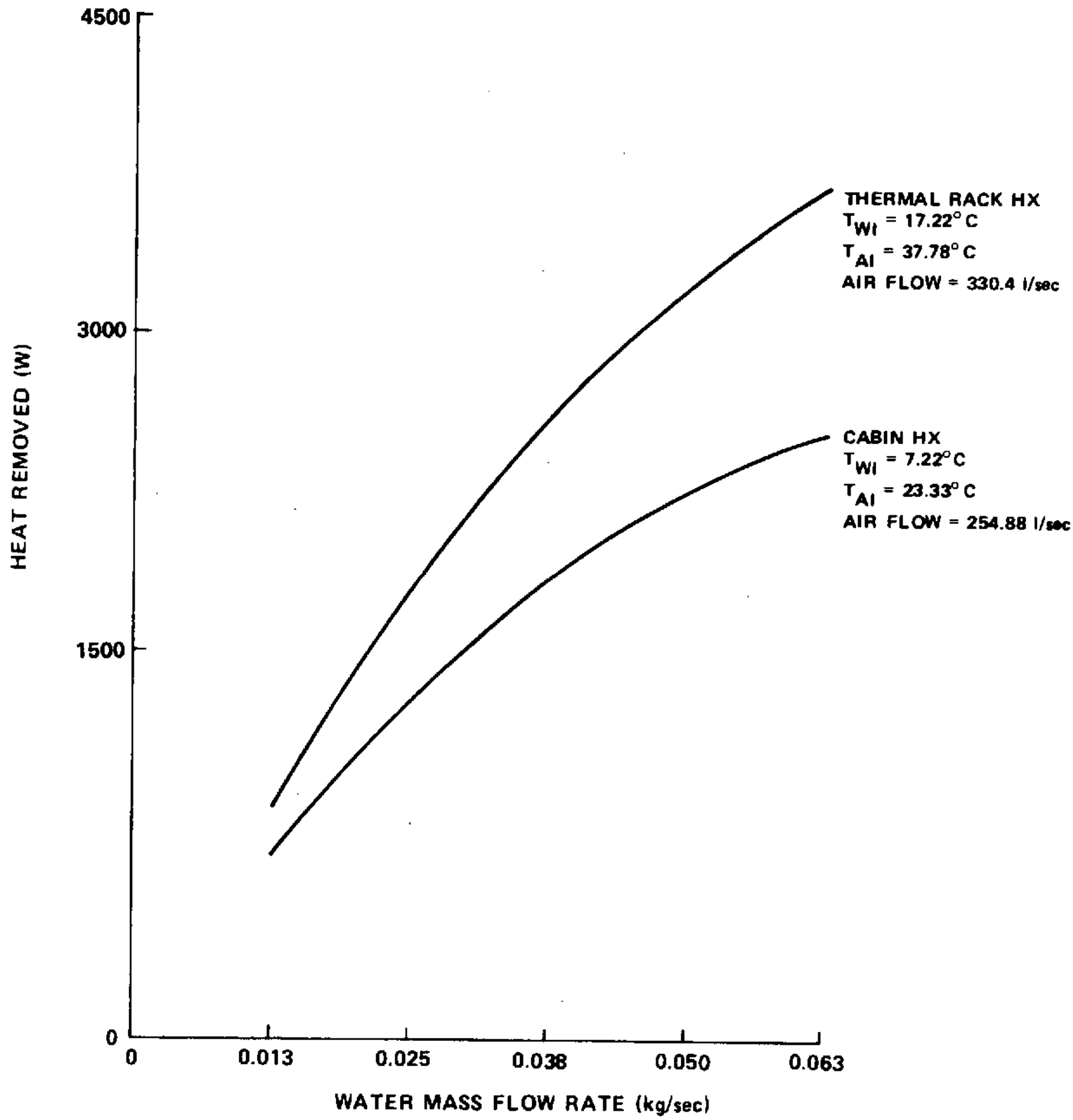

Figure 15. Cabin/Equipment Heat Exchanger heat removal performance.

VENTILATION FAN
(Skylab Program)

Vendor Airesearch Division of The Garrett Corporation

Vendor P.N. 605732-2-1

Usability This unit was not utilized for Spacelab because of its high unit cost and its low ΔP capability.

FAN HISTORY

Problems were encountered during Skylab development of the ventilation fans (P.N.605732-2-1). The fan was originally developed and used in the Apollo Program as a device to provide crew ventilation after spacecraft landing but prior to crew exit. The Skylab vehicle exposed fan to higher vibration levels and longer run times and required lower noise levels than Apollo. Consequently, due to the more stringent requirements imposed on fan design, a number of changes were required after initial procurement—larger bearings, redesigned bearing preload springs, new lubricant, suppression of electronic feedback, and use of acoustic noise suppressors.

In order to reduce the high unit cost ($\approx$ \$12 000 each) and improve the ΔP of the fan, a program was initiated to develop a reliable low cost fan.

Fan 2910V-4-1 was developed and qualified as a directly interchangeable fan (for Skylab application requiring relatively high ΔP). The remaining fans shown have not been qualified and were being considered for further development for future programs such as Spacelab. The idea was to establish low cost, reliable, and relatively quiet fans. A determination was to be made as to selection of a centrifugal or vaneaxial type of fan as best choice for the main ventilation fans for Spacelab. Except for the Skylab fans, the fan data is preliminary.

DESCRIPTION

This very efficient fan (Fig. 16) with a light commutated brushless dc motor was originally used for the Apollo CSM.

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Application in Skylab required bearing spring redesign, new lubricant, and electronics modification. Acoustic noise suppression devices were required to meet noise level criteria. An acoustic shroud encloses the fan and allows rapid removal/replacement of the fan during flight. Its performance in Skylab has been flawless. The unit weighs 4.49 kg (2.04 kg without acoustic shroud).

Figure 17 is a compilation of flow performance plots (generated curve for the fan under discussion is labeled by 605732-2-1). Fan input power versus flow rate plots are shown in Figure 18. Figure 19 depicts fan noise levels. (Fan noise generation for P.N. 605732-2-2-1 is not shown in Figure 19 because it was tested under different conditions.) The reader should refer to these three figures in examining fan performance characteristics for other fans described in this report.

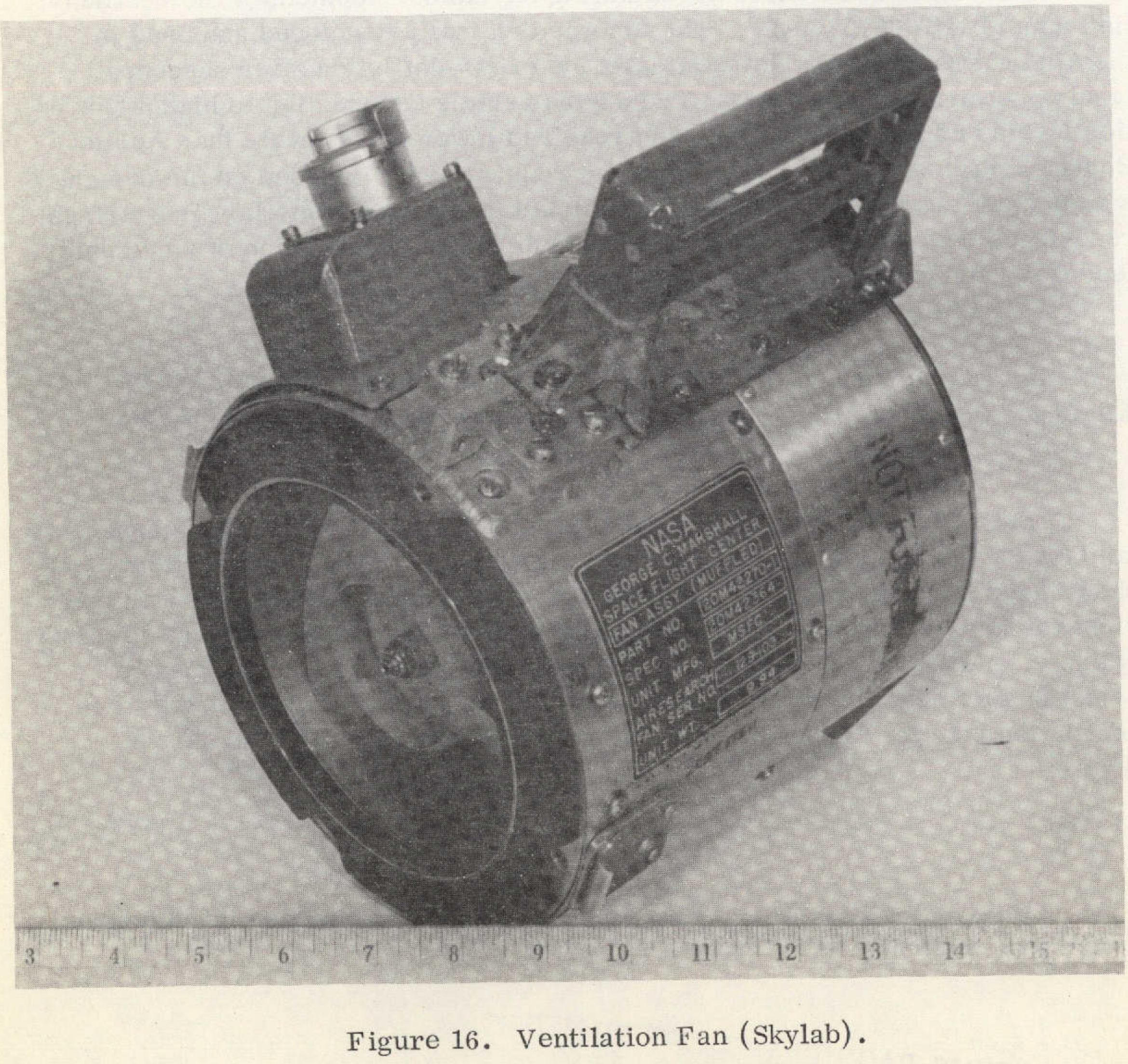

Figure 16. Ventilation Fan (Skylab).

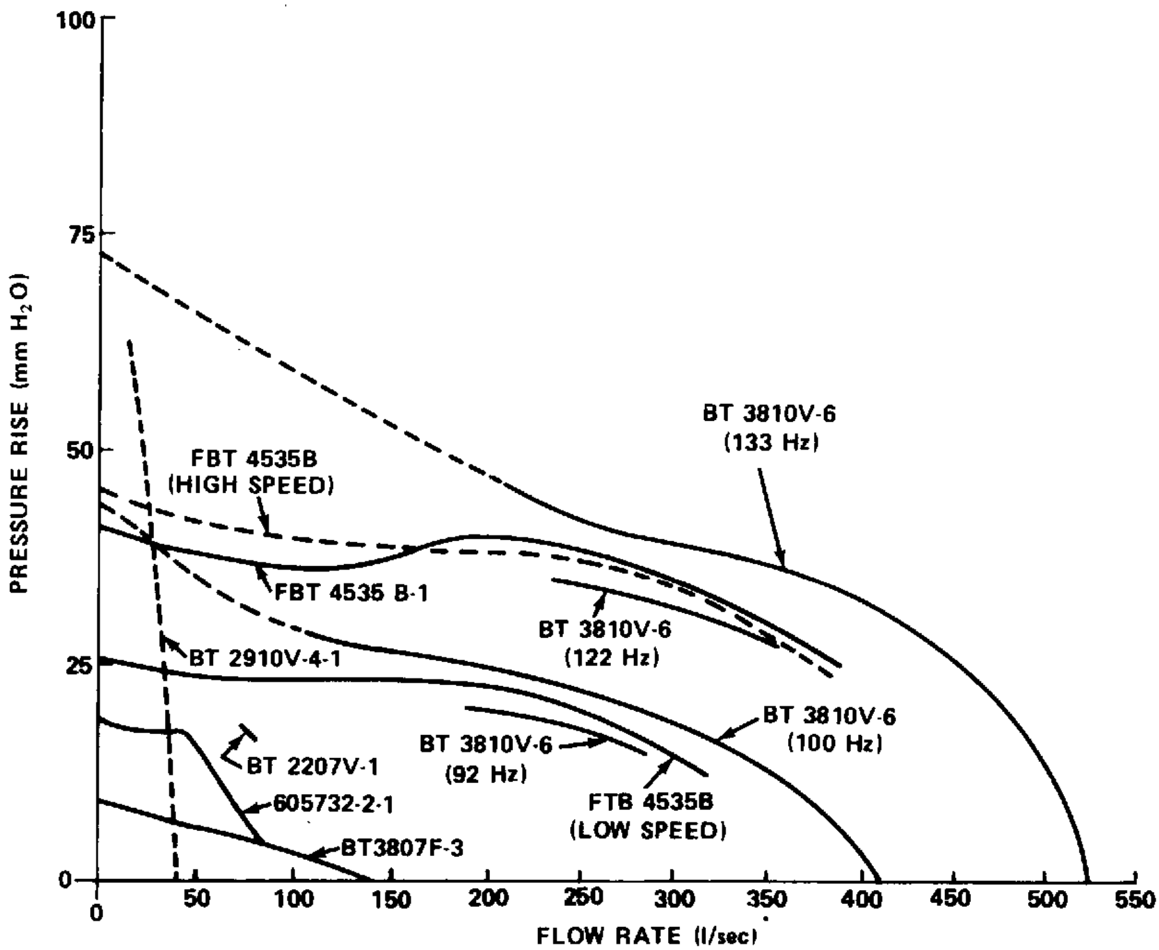

Figure 17. Compilation of fan flow performance plots.

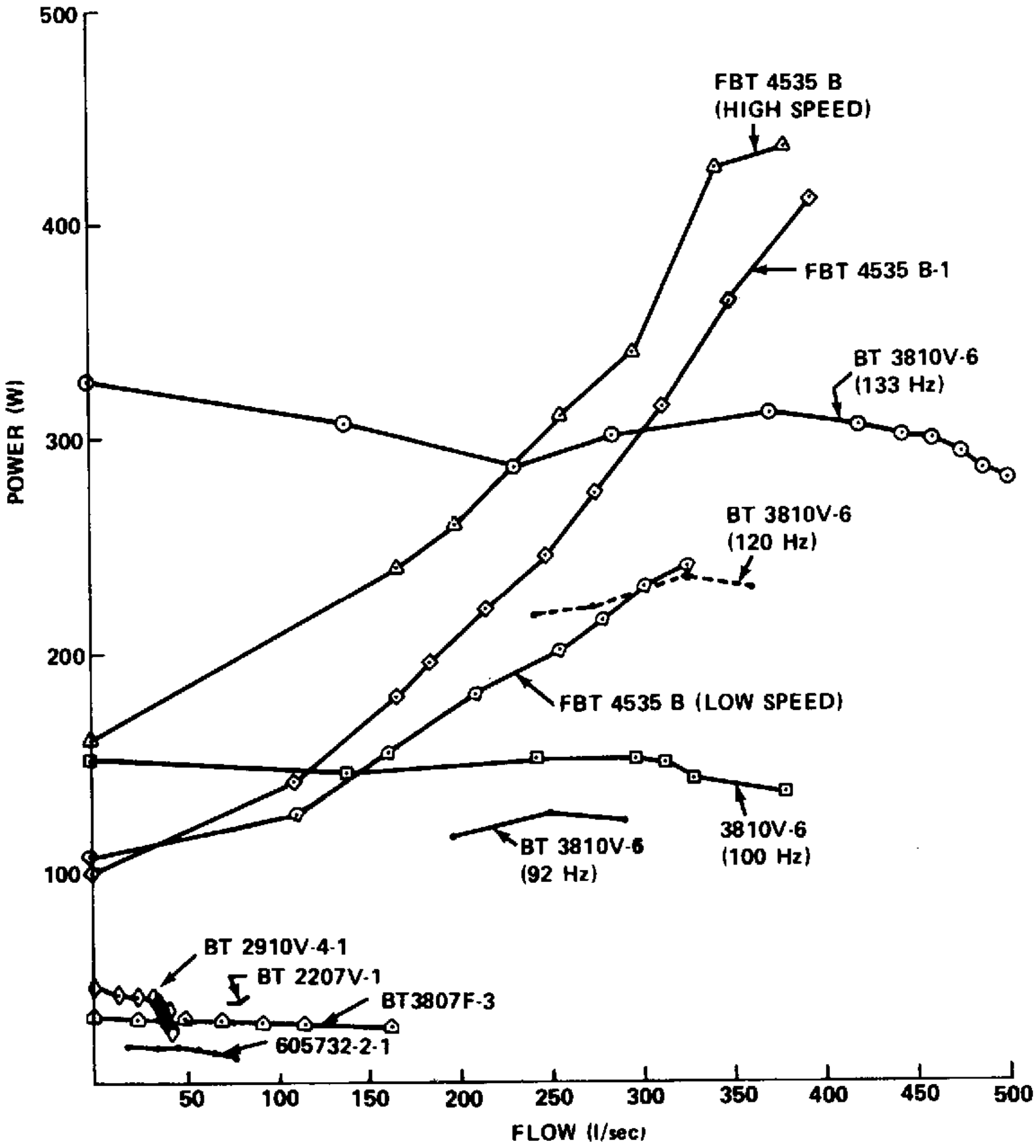

Figure 18. Compilation of fan input power plots.

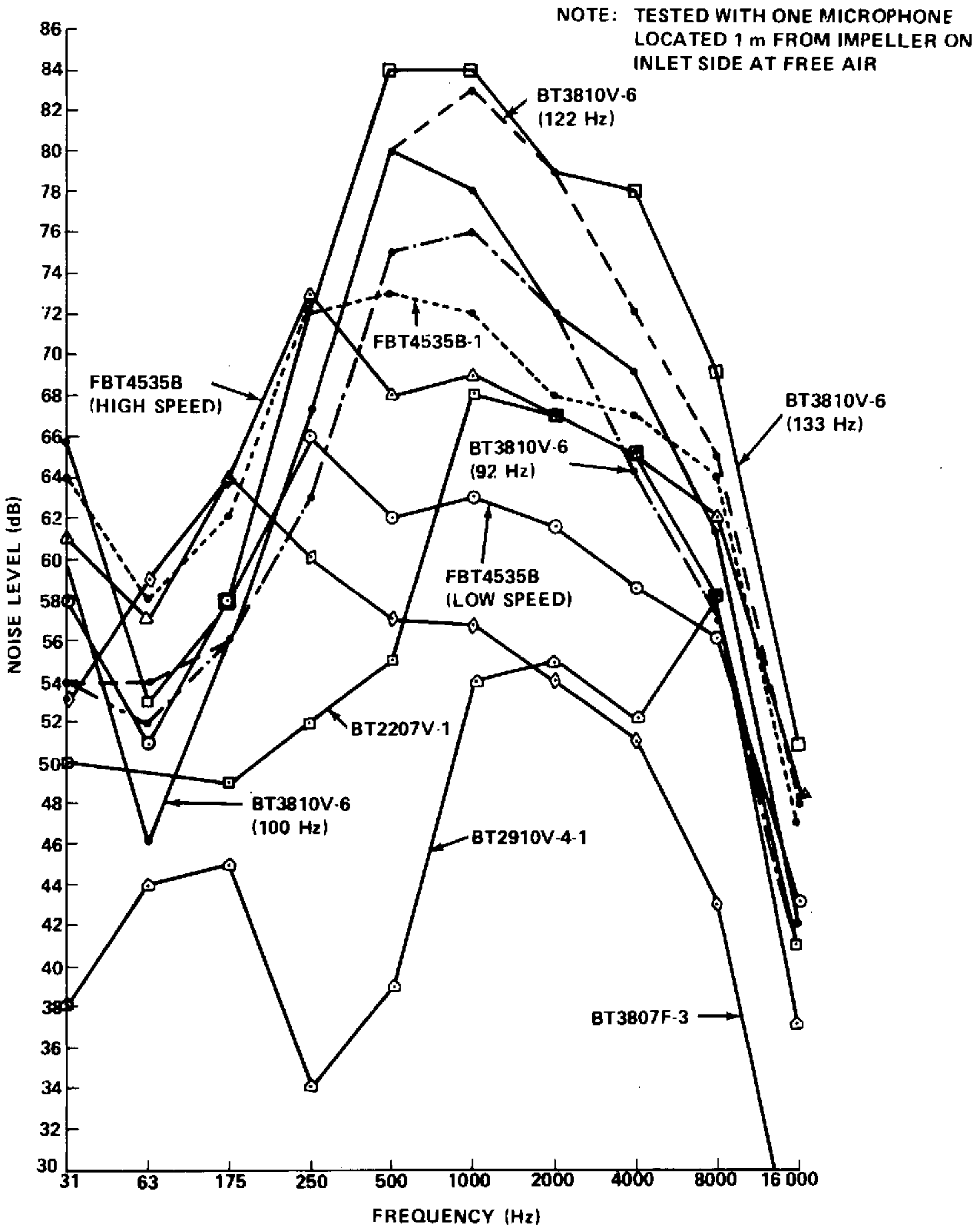

Figure 19. Compilation of fan noise level generation plots.

CONDENSING HEAT EXCHANGER FAN

Vendor	IMC Magnetics Corporation, Westbury, New York
Vendor P.N.	BT2910V-4-1
Usability	Previous application was as backup fan for Skylab ventilation fan. Item was qualified but not flown in Skylab. Primary concern in utilizing this item in Spacelab is life test verification at 1.01×10^5 N/m^2 (Skylab test was performed at 3.45×10^4 N/m^2). (See numbers M170 and M171 in Figure 1.)

DESCRIPTION

The unit shown in Figure 20 is utilized in baseline Spacelab design. It is powered by a low voltage ac induction motor. The fan contains an integral inverter with adjustable output frequency, permitting small adjustments in rpm. Input voltage is 28 Vdc.

The inverter and acoustic shroud were designed and installed at NASA MSFC. Total weight is 5.67 kg; the basic fan supplied by vendor weighs 2.27 kg. Performance curves for flow (ΔP), power, and acoustics of the basic fan may be found in Figures 17, 18, and 19. Input power was 21.1 Vac, 3ϕ, 138 Hz for those data. (The inverter has little effect on flow, ΔP, but increases power by $\approx$ 20 percent. The acoustic shroud has little effect on acoustics except when combined with inlet/outlet mufflers — then, noise is reduced by $\approx$ 15 dB.)

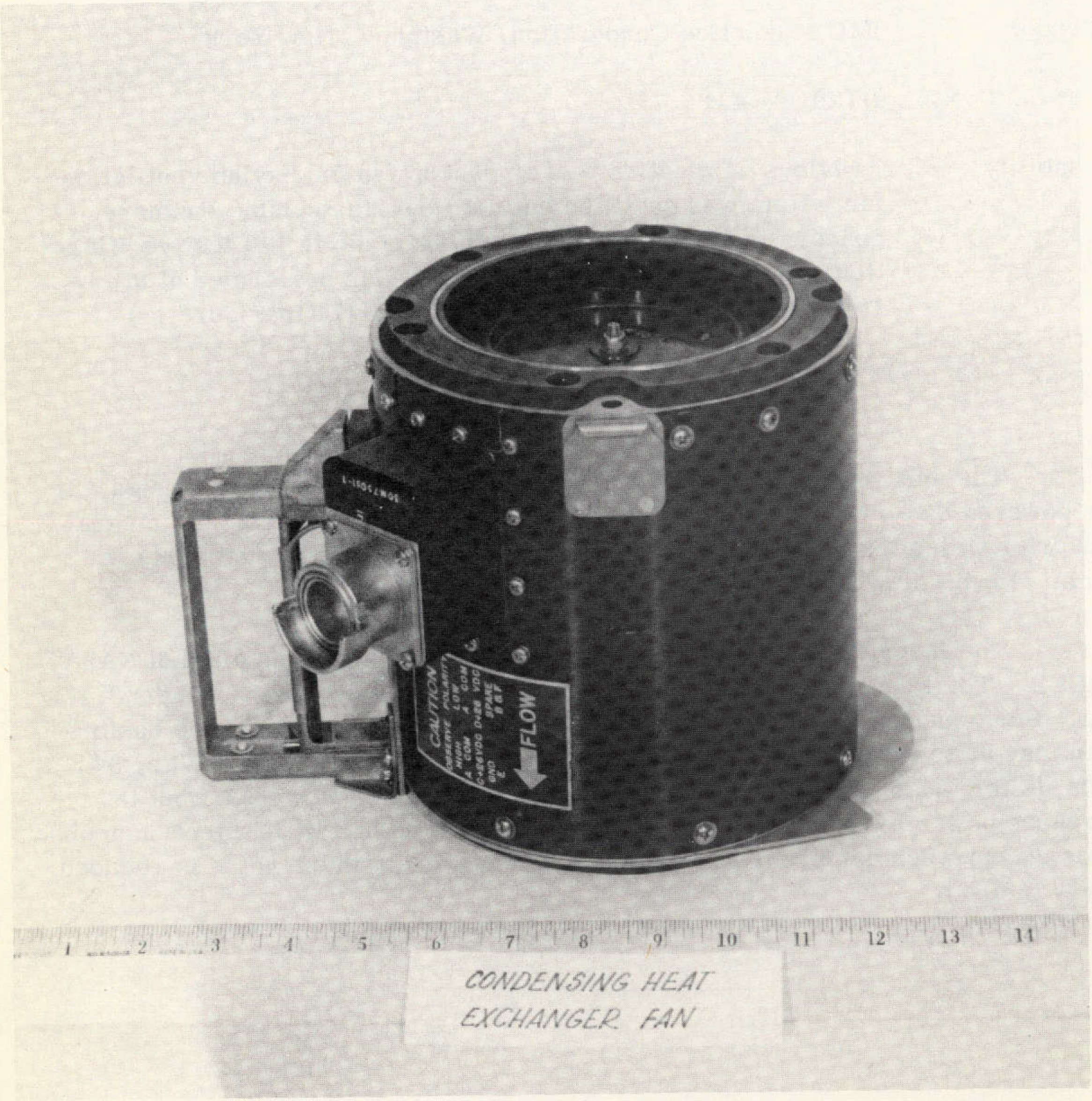

Figure 20. Condensing Heat Exchanger Fan.

CABIN/EQUIPMENT VENTILATION FAN
(Low Cost Development)

Vendor	IMC Magnetics Corporation, Westbury, New York
Vendor P.N.	BT3810V-6
Usability	This item is new, low cost hardware. Additional development and qualification testing required. Acoustic noise suppressors would be required.

DESCRIPTION

The unit shown in Figure 21 was selected as the baseline for both the cabin and the equipment ventilation systems. The new development was initiated to get a better understanding for low cost, vaneaxial fans as compared to centrifugal fans and to be in a better position to evaluate fan power and acoustic design requirements.

Fan motor is ac with a cavity provided for mounting an inverter to drive the fan at either of two speeds. The two speeds are the result of variations in input power — 23 Vac, 3ϕ, 92 Hz and 28 Vac, 3ϕ, 120 Hz. This allows use of one type unit for two different applications; however, an integral inverter with two outputs is required, Weight of the unit is 6.35 kg. Performance curves may be found in Figures 17, 18, and 19. In addition to the above test points, data for the following conditions are included: 24 Vac, 3ϕ, 100 Hz and 31 Vac, 133 Hz.

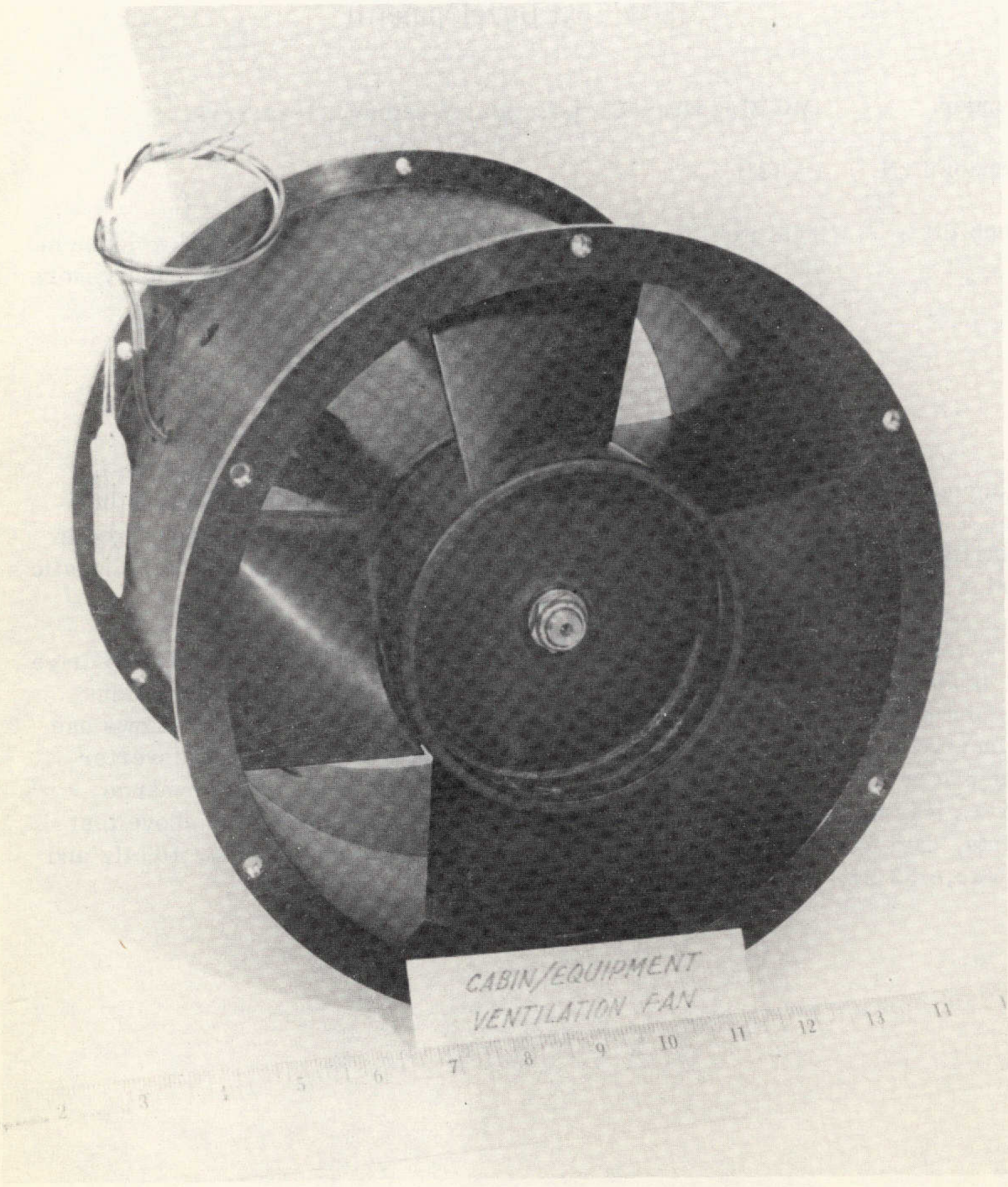

Figure 21. Cabin/Equipment Ventilation Fan.

CABIN/EQUIPMENT CENTRIFUGAL BLOWER
(Low Cost Development)

Vendor	IMC Magnetics Corporation, Westbury, New York
Vendor P.N.	FBT 4535B
Usability	This item is modified off-the-shelf type hardware. Additional development plus qualification would be required. Weight/power and ruggedness need improvement. A primary concern is evaluation to determine whether a centrifugal or a vaneaxial device is most suitable for this application. (See numbers M181 and M184 in Figure 1.)

DESCRIPTION

The Cabin/Equipment Centrifugal Blower (Fig. 22) is an alternate to the baseline for both the cabin and the equipment ventilation systems. The new developmentwas initiated to get a better understanding for centrifugal fans as compared to vaneaxial fans and to be in a better position to evaluate fan power and acoustic design requirements. The fan motor is low voltage ac direct drive. An inverter is required to operate the unit at either of two speeds. The two speeds are the result of variations in input power — 23 Vac, 3ϕ , 85 Hz and 30 Vac, 3ϕ, 110 Hz. This allows use of one type unit for two different applications; however, an inverter with two outputs is required. Weight of unit is 14.97 kg. Performance curves may be found in Figures 17, 18, and 19.

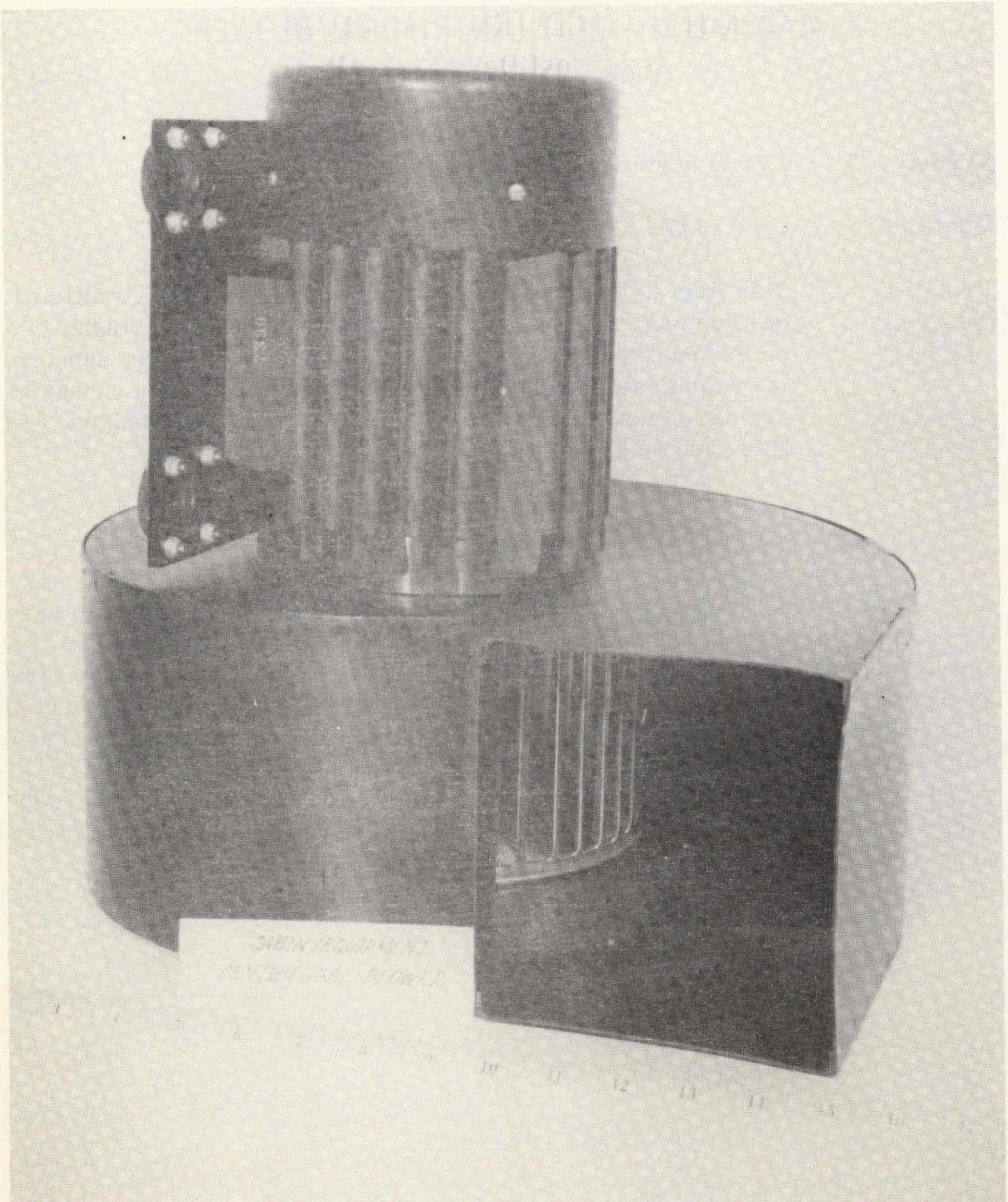

Figure 22. Cabin/Equipment Centrifugal Blower.

EQUIPMENT CENTRIFUGAL BLOWER
(Low Cost Development)

Vendor	IMC Magnetics Corporation, Westbury, New York
Vendor P.N.	FBT-4535B-1
Usability	**This item is modified, off-the-shelf type hardware. Additional** development plus qualification would be required. Weight, power, and ruggedness need improvement. A primary concern is evaluation to determine whether a centrifugal or vane-axial device is most suitable for this application. (See number M184 in Figure 1.)

DESCRIPTION

This unit, shown in Figure 23, is an alternate to the baseline for the equipment ventilation system. Its speed and size were dictated to a degree by the 60 Hz frequency. The idea was to evaluate a blower that operates off standard voltage and frequency (110 Vac, 60 cycle 3ϕ). Weight of unit is 14.74 kg. Performance curves may be found in Figures 17, 18, and 19.

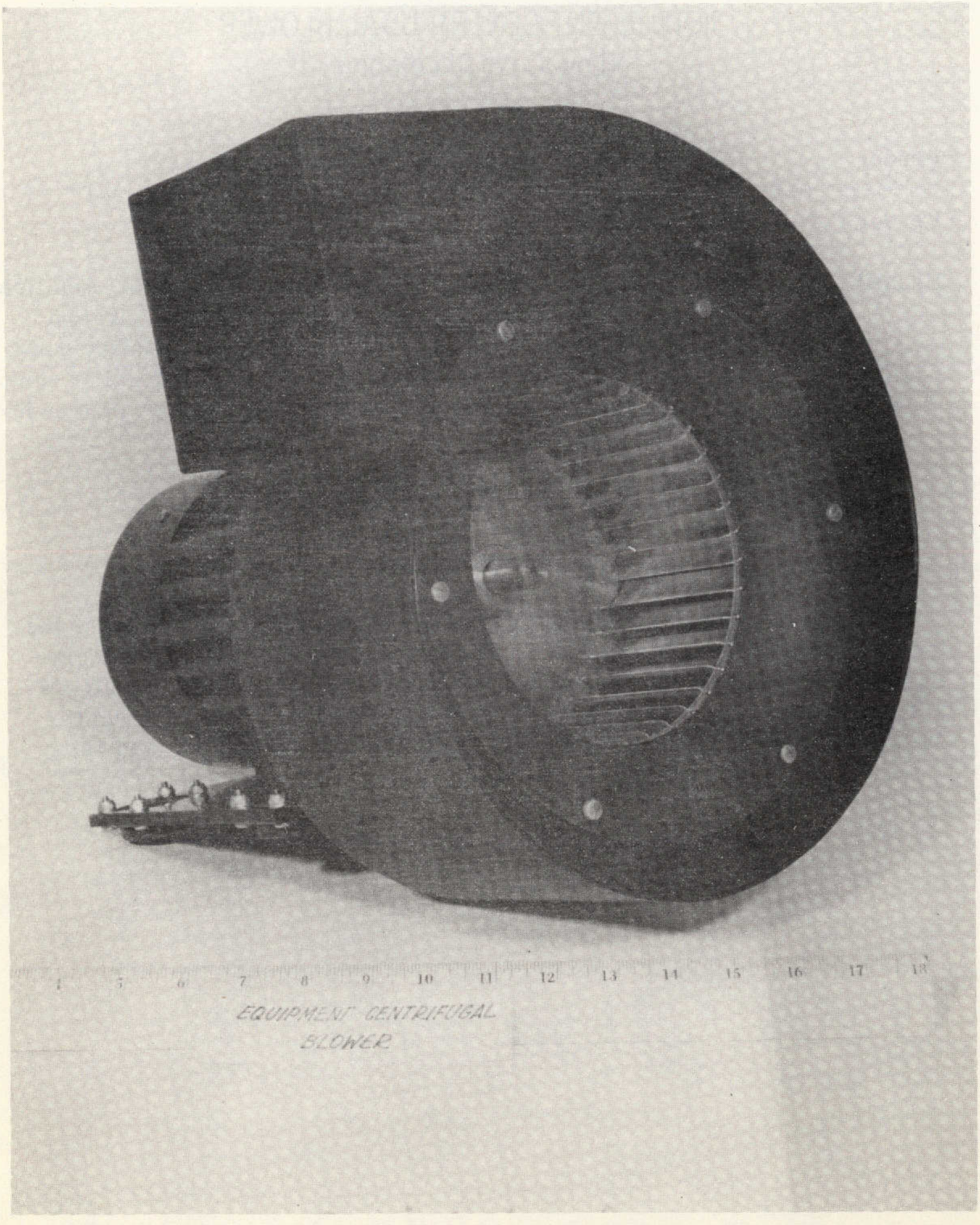

Figure 23. Equipment Centrifugal Blower.

EQUIPMENT RACK VENTILATION FAN
(Low Cost Development)

Vendor IMC Magnetics Corporation, Westbury, New York

Vendor P.N. BT3807F-3

Usability This item is new, low cost hardware. Additional development and qualification testing required.

DESCRIPTION

This unit (Fig. 24) is not utilized in baseline design. It is a low ΔP propeller fan driven by a 60 cycle, 115 volt induction motor. It could be used to provide additional ventilation and air cooling for equipment racks where localized high thermal loads exist. Weight of the unit is 2.27 kg. Performance curves are given in Figures 17, 18, and 19.

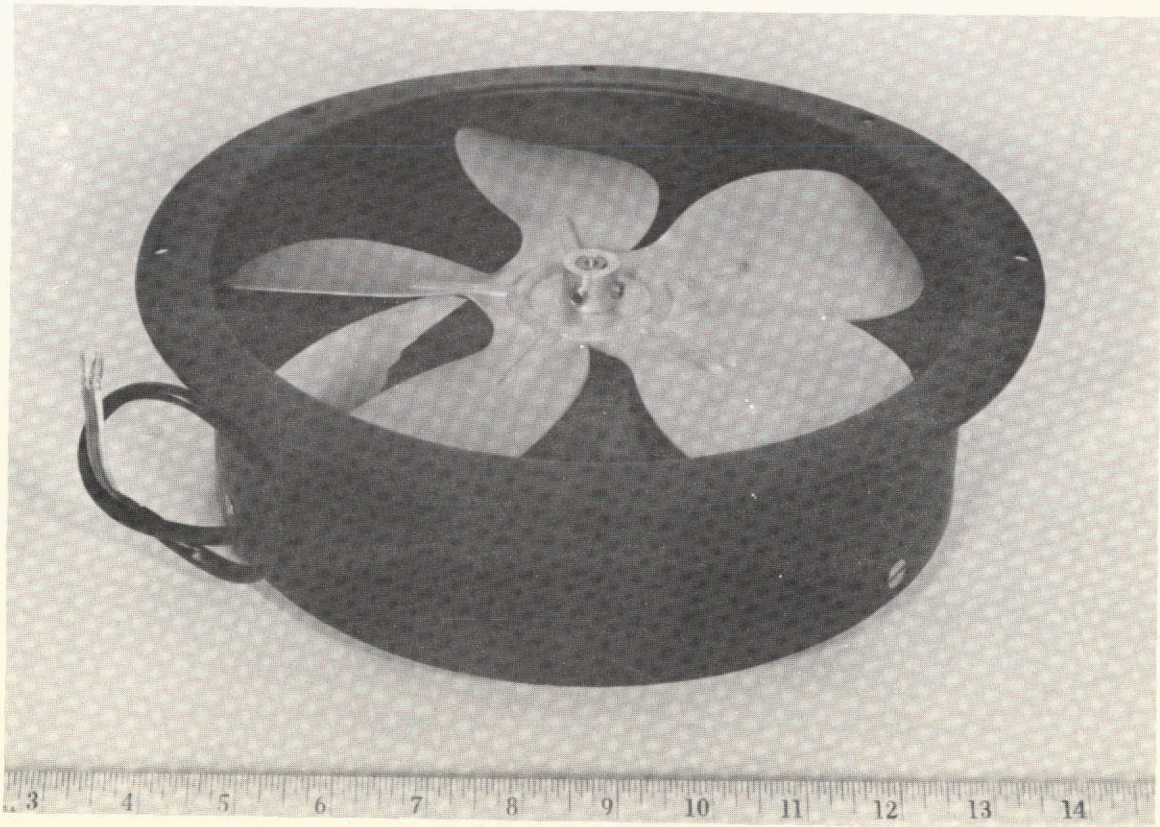

Figure 24. Equipment Rack Ventilation Fan.

RACK HEAT EXCHANGER FAN
(Low Cost Development)

Vendor	IMC Magnetics Corporation, Westbury, New York
Vendor P.N.	BT2207V-1
Usability	This item is new, low cost hardware. Additional development and qualification testing required. Unless well isolated from cabin noise, suppressors would be required.

DESCRIPTION

The Rack Heat Exchanger Fan (Fig. 25) is not utilized in baseline design. It is a medium ΔP device powered by a low voltage ac induction motor. An integral inverter could be mounted in rear of fan. This fan could be used for supplementary equipment back cooling by providing air flow across a rack-mounted heat exchanger. Input power is 30 Vac, 3ϕ, 200 Hz. Weight is 1.47 kg. Performance curves may be found in Figures 17, 18, and 19.

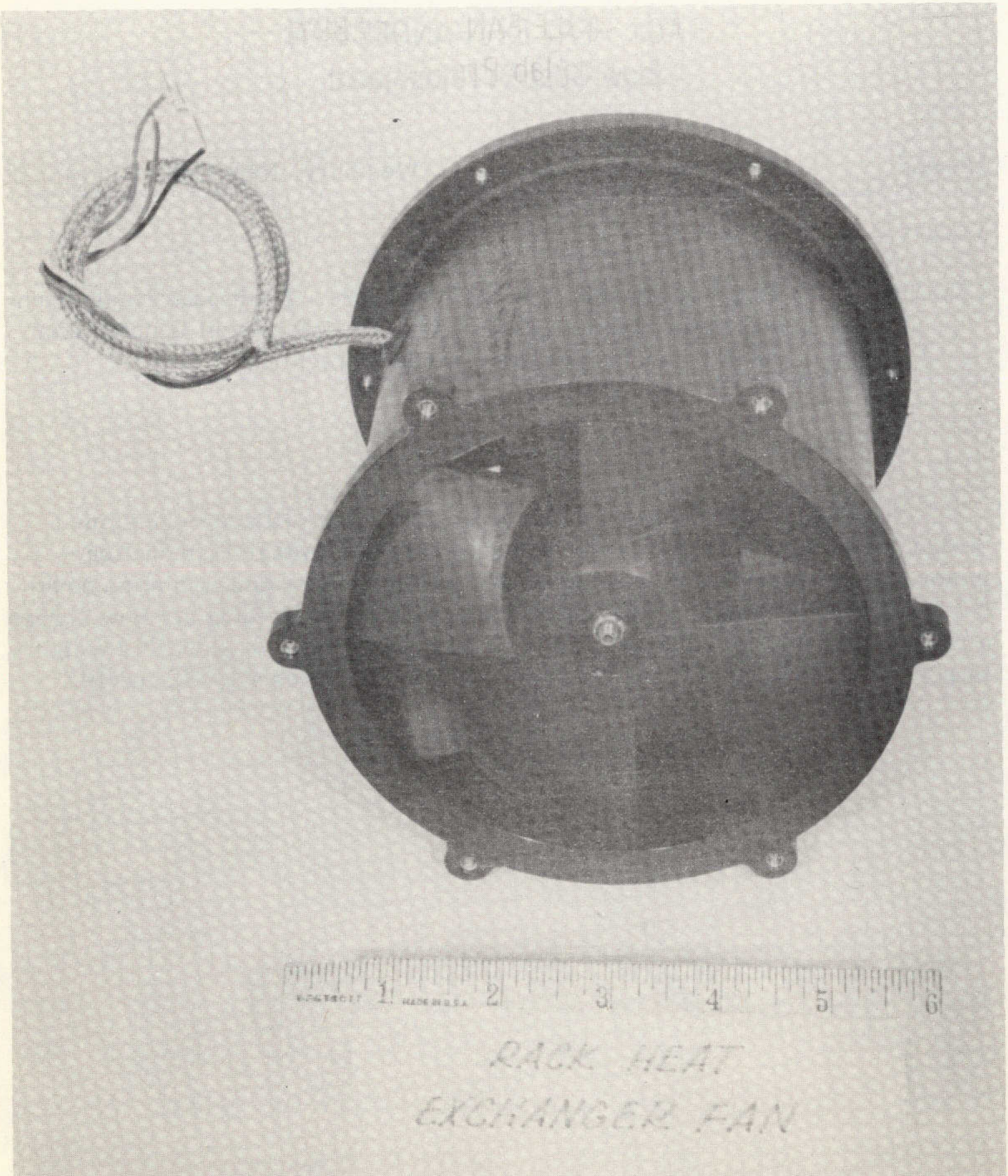

Figure 25. Rack Heat Exchanger Fan.

PORTABLE FAN ASSEMBLY
(Skylab Program)

Vendor	McDonnell Douglas (West Div.), Huntington Beach, California
Vendor P.N.	1B82557
Usability	Not recommended for Spacelab. Selection of a low rpm propeller fan is preferable (if a portable fan were required).

DESCRIPTION

This unit (Fig. 26) was not selected for the baseline design. Its bulk is due to noise suppressors required to meet acoustic noise levels. Selection of most desirable fan for this application (propeller fan) was eliminated by requirement to use a common ventilation fan for all applications. The unit includes an adjustable air diffuser. A fan noise reduction of 15 dB sound pressure level (ref 2×10^{-5} N/m^2) was averaged over the speech interference level range (500 Hz to 4000 Hz measured in full octave bands). Dry weight of the unit is 15.42 kg (without fan). Fan (not shown) mounts (P.N. 605732-2-1, described earlier) are located in center of unit.

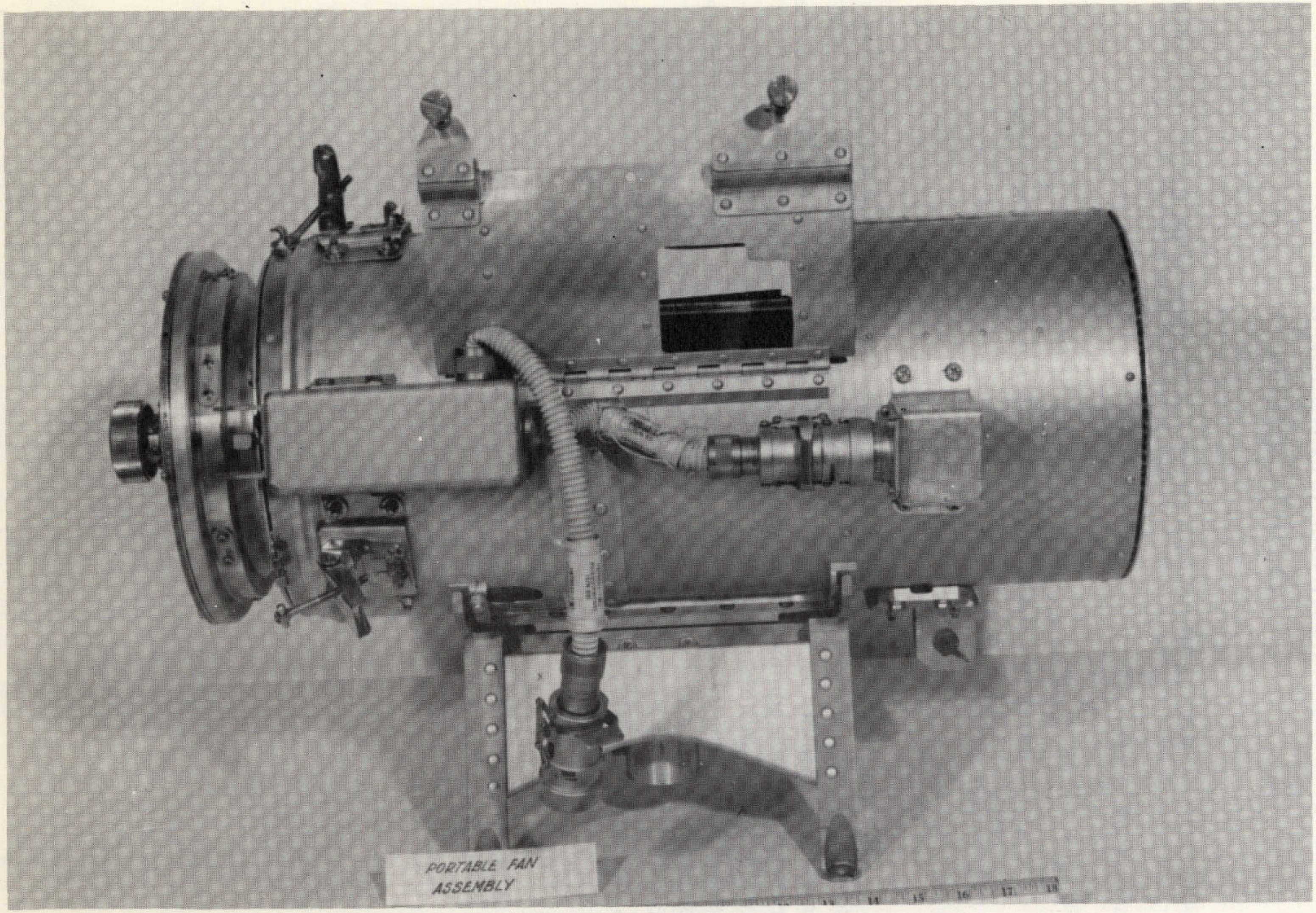

Figure 26. Portable Fan Assembly.

LiOH CANISTER (CO_2 REMOVAL)
(SSP Program)

Vendor	Hamilton Standard Division of United Aircraft Corporation, Windsor Locks, Connecticut
Vendor P.N.	SVSK 84408
Usability	Development/qualification test required. No problems anticipated. This item designed under Space Station Prototype (SSP) Program. (See numbers M176, M178, and M180 in Figure 1.)

DESCRIPTION

The LiOH Canister (Fig. 27) is utilized in the baseline Spacelab design. Three canister are required to handle CO_2 production for a 7-day mission. Provision exists to carry a fourth canister, if needed.

The canister's empty weight is approximately 10.34 kg. Each holds 7.89 kg of LiOH. The LiOH container may be withdrawn from the canister and substituted in flight without disturbing air duct connections on the canister. The band clamp used to hold the LiOH container in canister is shown in Figure 27. Air duct connections are on left end. The components shown at the bottom of the photograph are wave springs used to keep the LiOH under compression; This prevents the occurrence of voids by shifting of LiOH during vibration. The estimated flow/ΔP curve is shown in Figure 28.

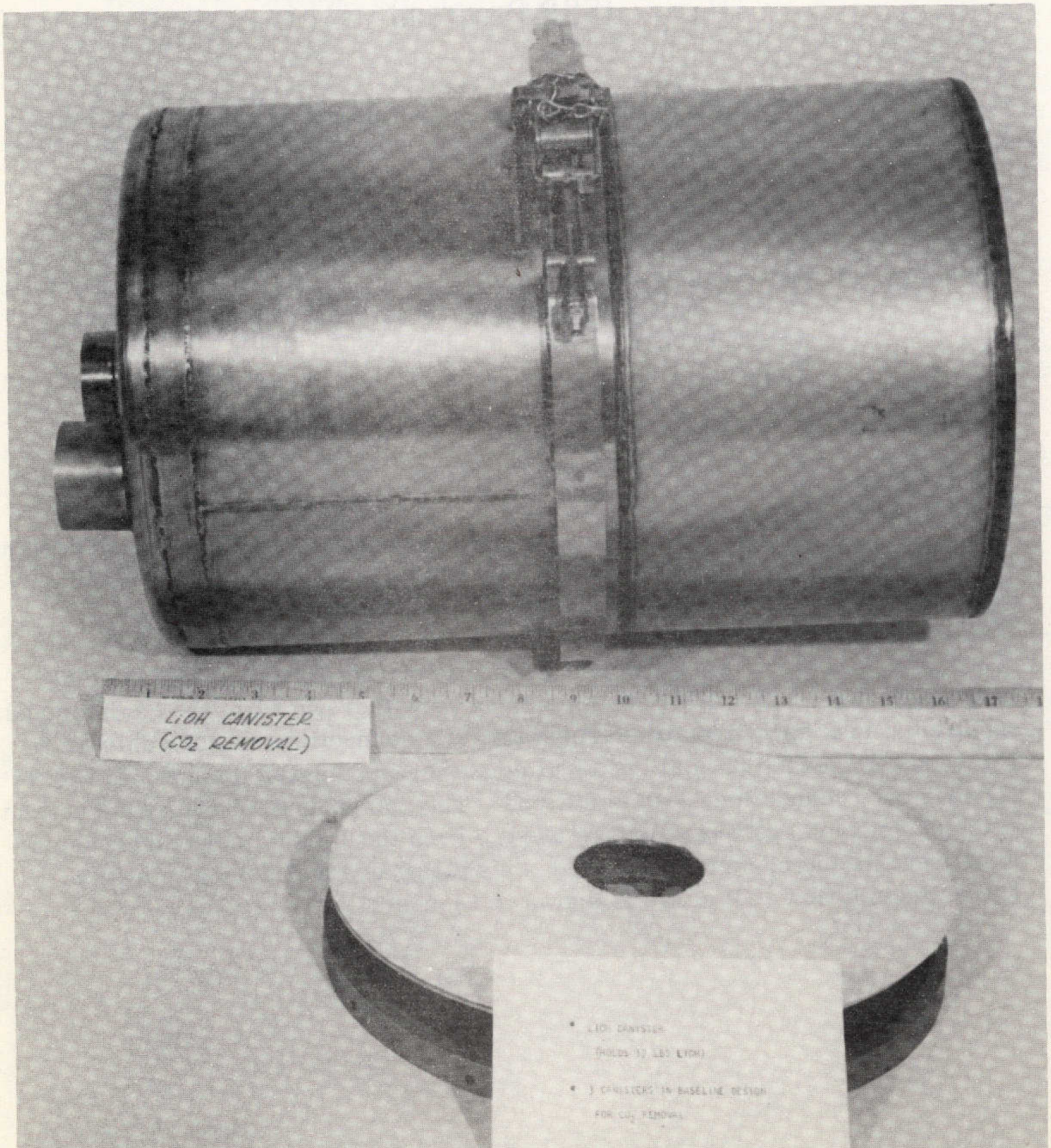

Figure 27. LiOH Canister (CO_2 removal).

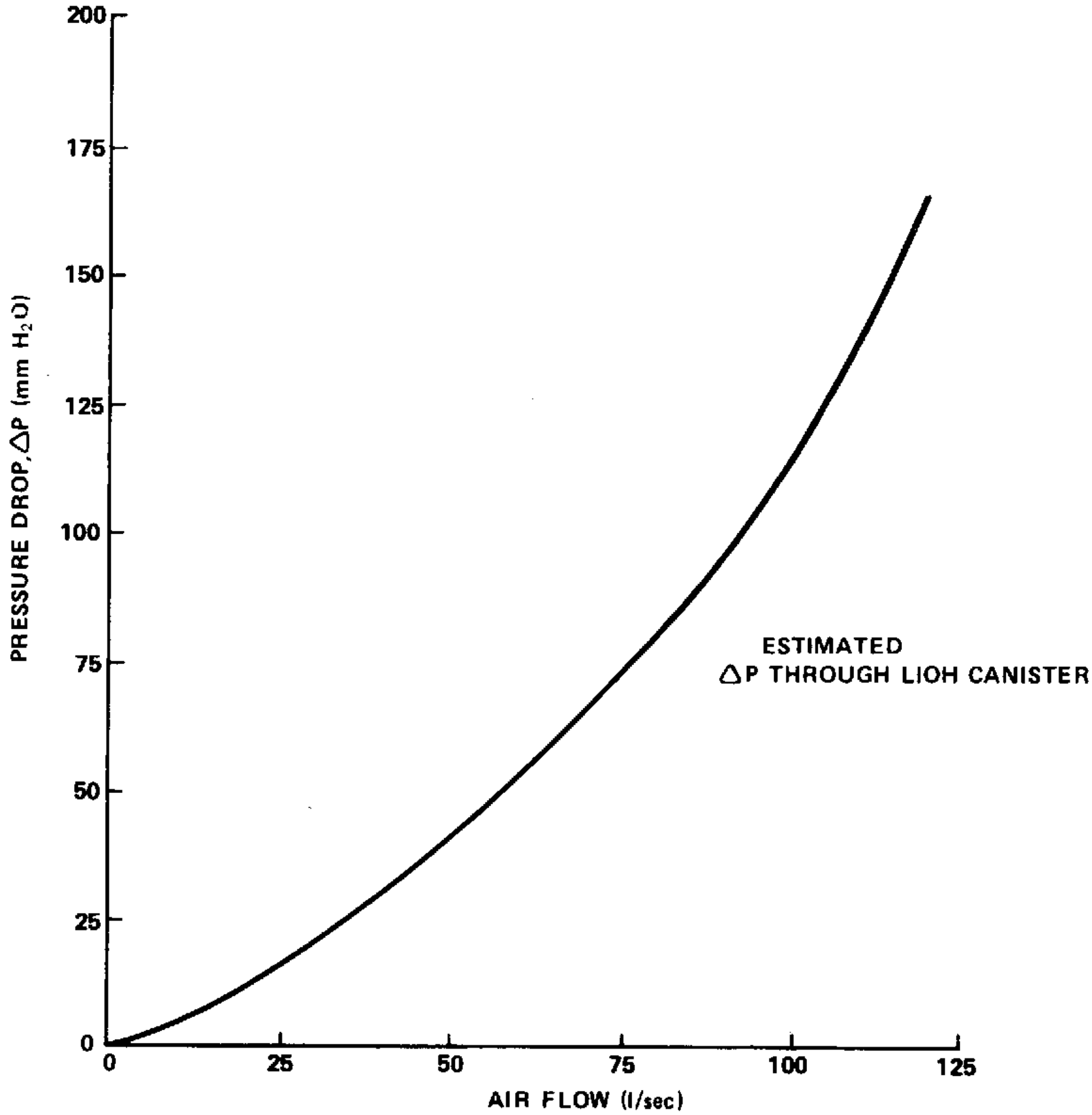

Figure 28. Estimated pressure drop and air flow rate LiOH Canisters.

WATER LOOP COOLANT PUMP
(Skylab Program — ATM)

Vendor	Airesearch Manufacturing Division of The Garrett Corporation, Los Angeles, California
Vendor P.N.	580745-1-1
Usability	Little additional qualification test required. Compatibility test with coolant required. (See number M41 in Figure 1.)

DESCRIPTION

The unit shown in Figure 29 was selected as the MSFC Spacelab Phase B baseline cabin coolant loop pump. The pump is centrifugal-driven by an induction ac motor through a magnetic coupling (no dynamic seals required). It contains two pump/motors. The magnetic coupling and pump/motor assembly for one of the two pumps is shown in Figure 30. Dry weight of the pump assembly is 5.44 kg.

The design requirements of the pump assembly for the ATM Program are compared to specifications for the Spacelab in Table 5. The flow, ΔP, and power properties are shown in plotted form in Figure 31. It should be noted that the curve shown is for the pump motor operating with a quasi-square wave output from the flight design inverter. Pump performance improves some when a sine wave, three-phase power supply is available.

TABLE 5. COMPARISON OF ORIGINAL (ATM) AND SPACELAB DESIGN REQUIREMENTS FOR THE WATER LOOP COOLANT PUMP

Parameter	Original Application	Spacelab Application
Medium	80/20 methanol/water, GN_2, air, He purge	Water
Pressure	344.75×10^3 N/m^2 gage operating 517.13×10^3 N/m^2 gage proof 861.88×10^3 N/m^2 gage burst 69 N/m^2 abs. or less vacuum with 101.36×10^3 N/m^2 abs. external pressure	344.75×10^3 N/m^2 gage operating 69 N/m^2 abs. or less vacuum with 101.36×10^3 N/m^2 abs.
ΔP and Flow	0.113 ± 0.0063 kg/sec at 213.75×10^3 N/m^2	See Figure 31 for water medium
Power	115 W max to either motor after startup Input from inverter is 400 Hz quasi-square wave 3ϕ, 21.15 Vac rms ϕ to ϕ and 12.2 Vac rms ϕ to neutral	See Figure 31 for water medium
Temperature	9.4 to 12.2°C normal; must be able to start and run for 24 hours at any temperature from -53.8 to 37.7°C	4.4 to ≈37.7°C
Check Valve	Each pump has a check valve to prevent backflow when not running	
Life	Over 9500 hr (running); life test still in process	

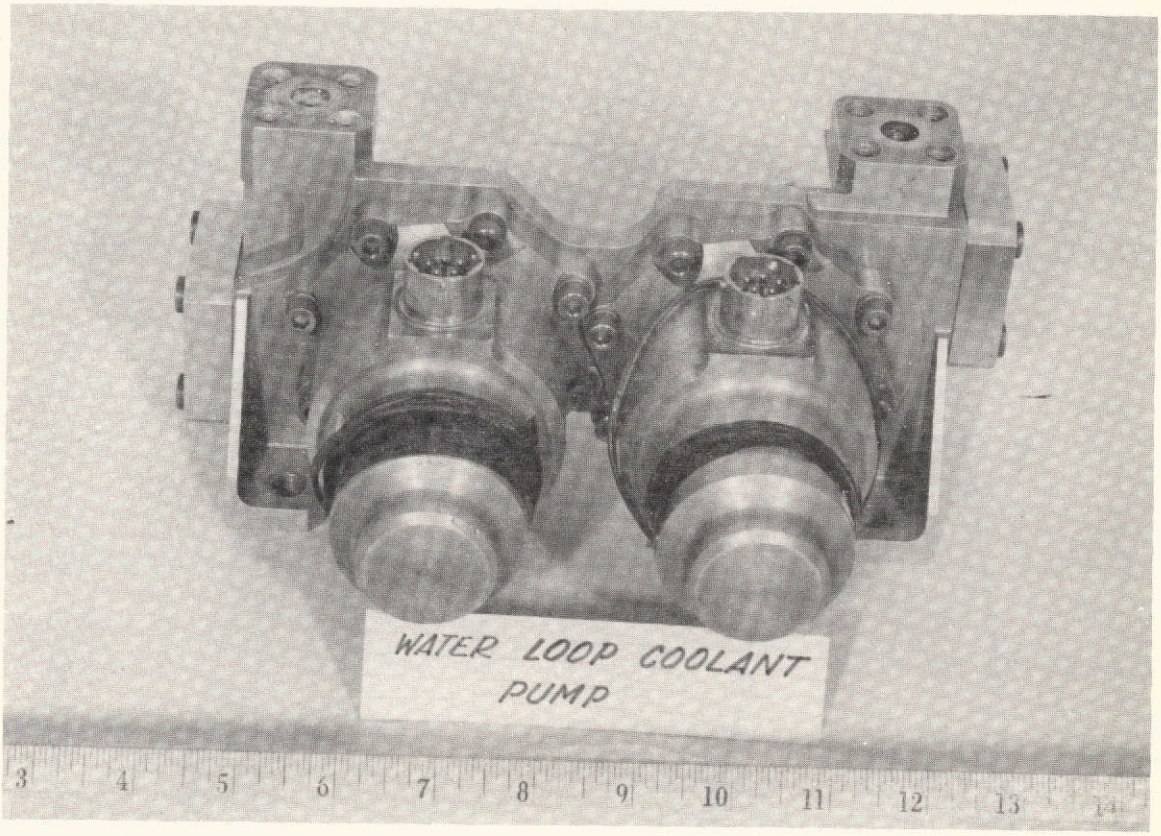

Figure 29. Water Loop Coolant Pump.

WORKING MEDIUM : METHANOL AND WATER
TOTAL CAPACITY : 0.113 kg/sec AT 10°C
PRESSURE RISE : 213.75×10^3 N/m^2
MAX OUTLET PRESSURE : 344.75×10^3 N/m^2
DESIGN : 2 PUMPS WITH MAGNETIC CLUTCH
AND BRUSHLESS 12.2 V, AC, 400 Hz
MOTOR; 11 000 rpm

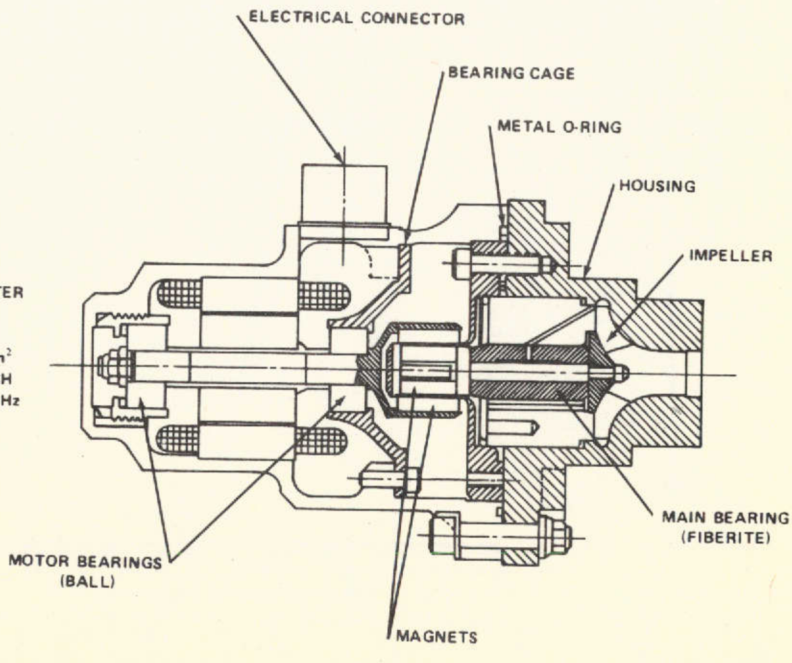

Figure 30. Cutaway view of Water Loop Coolant Pump.

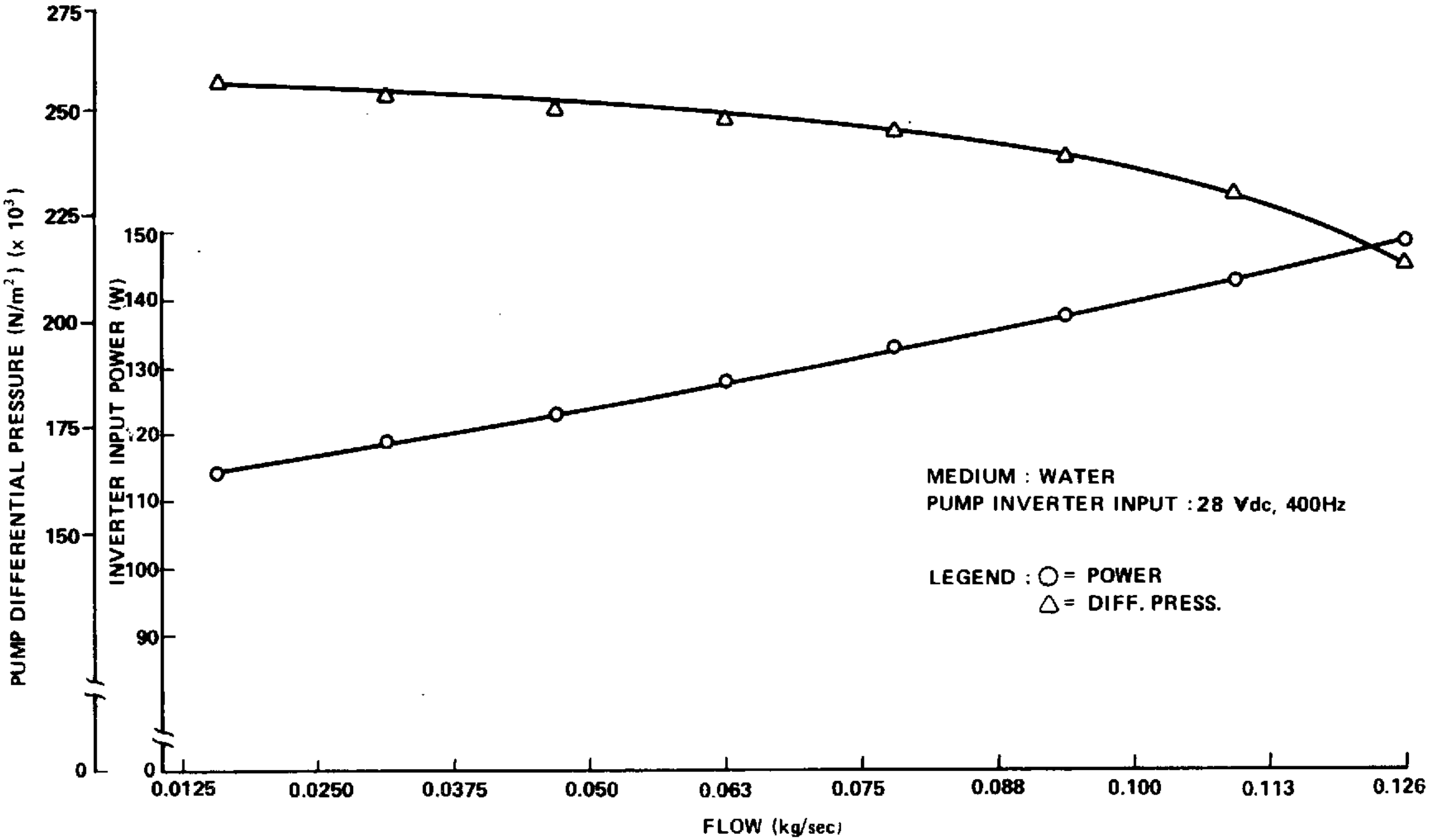

Figure 31. ATM-TCS pump characteristics.

WATER LOOP SUBLIMATOR
(Saturn/Apollo Program – IU)

Vendor	Hamilton Standard Division of United Aircraft Corporation, Windsor Locks, Connecticut
Vendor P.N.	SV711091-1
Usability	Primary concern in utilizing this item for Spacelab is inadequate knowledge of performance at the lower coolant flow rates. Additional performance tests will be required. This device is difficult to fabricate and there is some question as to whether vendor has maintained fabrication technique. (See number M43 in Figure 1.)

DESCRIPTION

This unit (Fig. 32) was selected as the baseline "water boiler" and is located in the cabin coolant loop. At the time of its development (1963-1965), the unit was considered an advancement in state-of-the-art "water boilers." It required a rather extensive development program but Saturn/Apollo flight performance has been flawless. The unit is brazed stainless steel with nickel porous plates. Dry weight of the unit (without the preflight heat exchanger) is 24 kg.

The cutaway view (Fig. 33) shows the unit assembly and the construction of each sublimator module. The unit has six full modules and two half modules. (A full module has a porous plate on both sides of the coolant (M/W) passage.) The original IU application design requirements are compared to the Phase B baseline in Table 6.

TABLE 6. COMPARISON OF ORIGINAL (SATURN/APOLLO IU) AND SPACELAB DESIGN REQUIREMENTS FOR THE WATER LOOP SUBLIMATOR

Parameter	Original Application	Spacelab Application
Medium	60/40 methanol/water	Water
Pressure	344.75×10^3 N/m^2 gage operating coolant 517.13×10^3 N/m^2 gage proof coolant 861.88×10^3 N/m^2 gage burst coolant No spec. exists for vacuum-filling coolant passages $25.51 \times 10^{+3}$ to 41.37×10^3 N/m^2 abs. operating evaporant 51.71×10^3 N/m^2 gage proof evaporant 86.19×10^3 N/m^2 gage burst evaporant	344.75×10^3 N/m^2 gage max operating Coolant passages will be vacuum filled at 69 N/m^2 abs. 13.79×10^3 to 34.47×10^3 N/m^2 abs. operating evaporant
Temperature, Flow, ΔP	Coolant inlet from 14.4 to 21.1°C at 0 to 0.983 kg/sec M/$\dot{W}$ with 24.13 N/m^2 max ΔP at max coolant flow	Coolant inlet from 7.1 to ≈37.7°C with 0.063 kg/sec water. ΔP will be very small
Heat Rej.	1 to 9 kW for 7 hr at design flow rates and pressures	2 to 8 kW for TBD hr per mission at above conditions
Outlet Temperature	0°C minimum after startup	Controlled between 4.4 and 7.1°C after startup

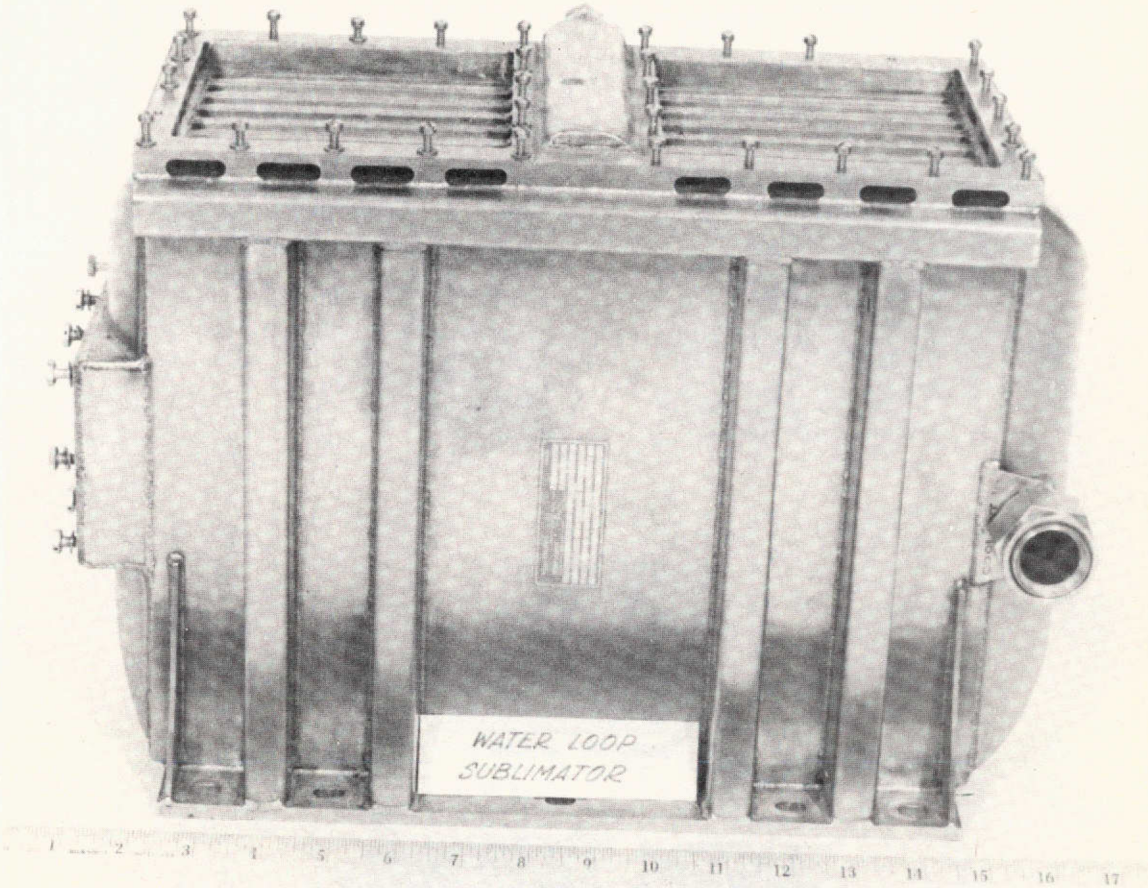

Figure 32. Water Loop Sublimator.

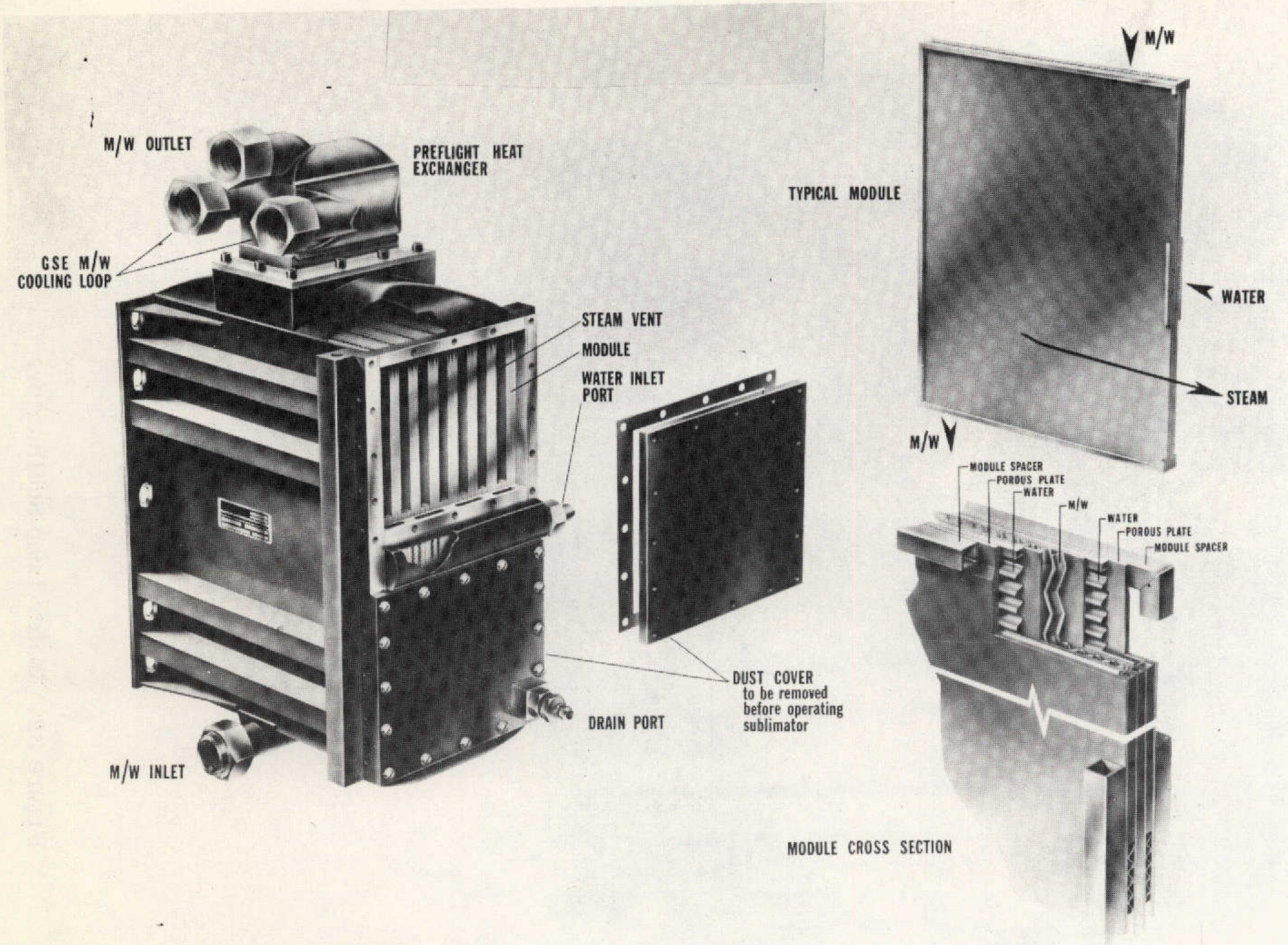

Figure 33. Cutaway view of Water Loop Sublimator.

INSULATION MATERIALS

Vendor — Crinkled Aluminized Mylar (With No Spacer) — McCord Manufacturing Company

Aluminized Mylar — McCord Manufacturing Company (Dacron Net Spacer) — Apex Mills

Superfloc Goldized Kapton — General Dynamics

Superfloc Aluminized Mylar — General Dynamics

Usability — Crinkled aluminized Mylar (with no spacer) selected for baseline cabin external insulation due to low weight

DESCRIPTION

Four candidate insulation materials were considered:

1. Crinkled aluminized Mylar with no spacer.

2. Aluminized Mylar (dacron net spacer).

3. Superfloc goldized Kapton.

4. Superfloc aluminized Mylar.

Item 1 (Fig. 34) was selected for Spacelab baseline because of very light weight and a good K value. All four items have a K value near 28×10^{-4} W/m^2°C, making them equal in this respect. Item 1, with a density of approximately 24 kg/m^3 was much lighter than item 2 which had a density of 80 kg/m^3. Item 3 was eliminated because of high expense and possible contamination of the external Spacelab and experiments by shedding of Superfloc fibers. Item 4 did not have the high cost of item 3 but was rejected because it presented the same problem of contamination.

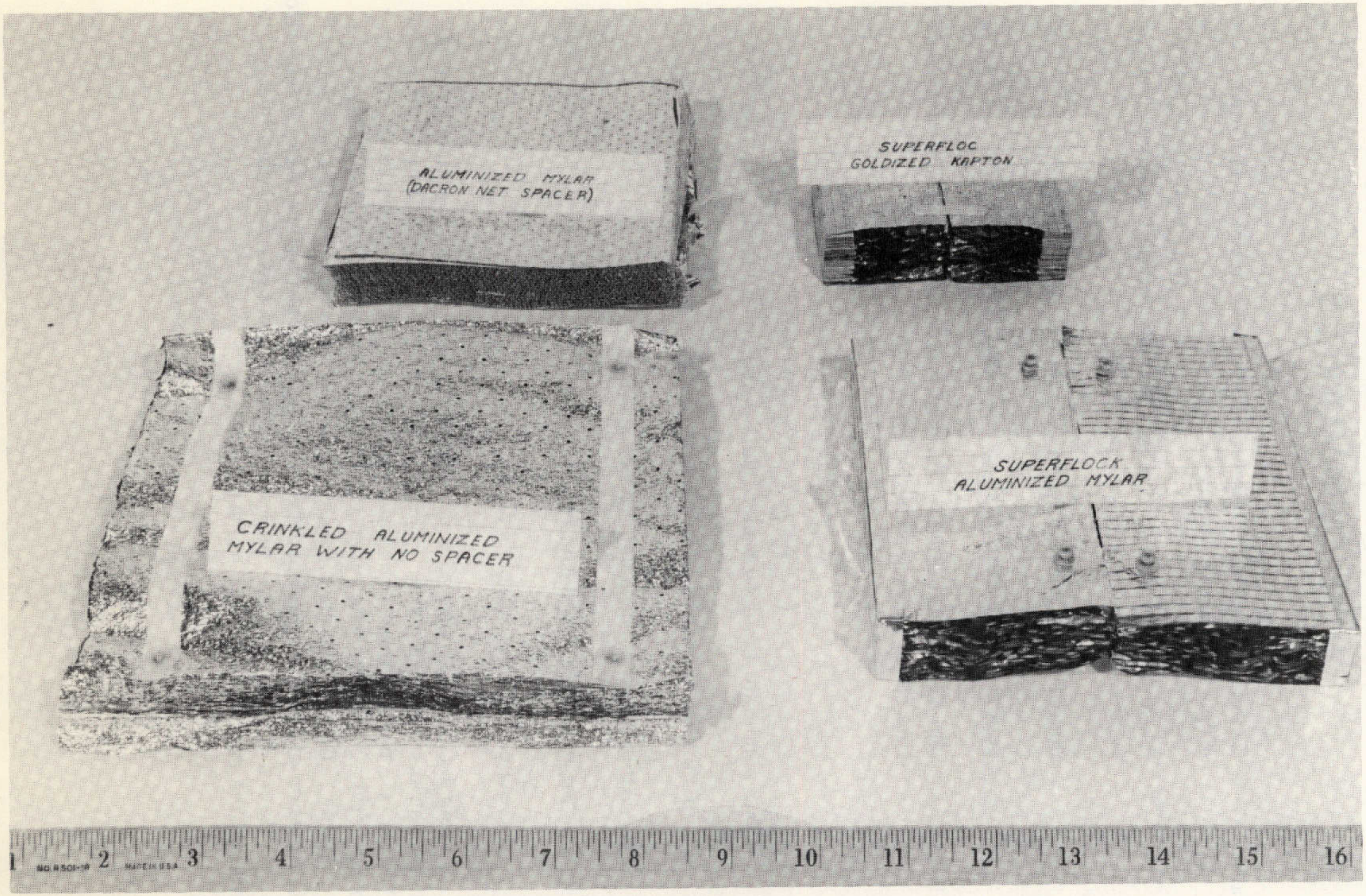

Figure 34. Insulation materials.

RADIATOR LOOP THERMAL CAPACITOR
(Skylab Program)

Vendor	McDonnell Douglas Corporation, St. Louis, Missouri
Vendor P.N.	61A830371-3
Usability	Primary concern in utilizing this item for Spacelab is selection of a new "wax" and its compatibility with the adhesives which bond wax chambers together. Another question is the total system heat rejection required of this item. (See number M8 in Figure 1.)

DESCRIPTION

This unit was selected for the baseline design. Figure 36 shows a single thermal capacitor module. A thermal capacitor assembly is made up of two of these modules. Figure 35 shows two of the assemblies installed on a panel.

The original design for Skylab consisted of a single module with three large "wax" chambers. The inability of original design to provide adequate ullage for wax expansion during phase change caused wax chamber side wall bulging and failure. The design was modified breaking the single module into two modules and the wax chanbers were also modified to provide a large number of honeycomb cells, each containing wax with its independent ullage.

Thermal capability will vary from 1056×10^3 to 2112×10^3 J total, dependent on "wax" selection and based on heat of fusion (116.2×10^3 to 232.4×10^3 J/kg).

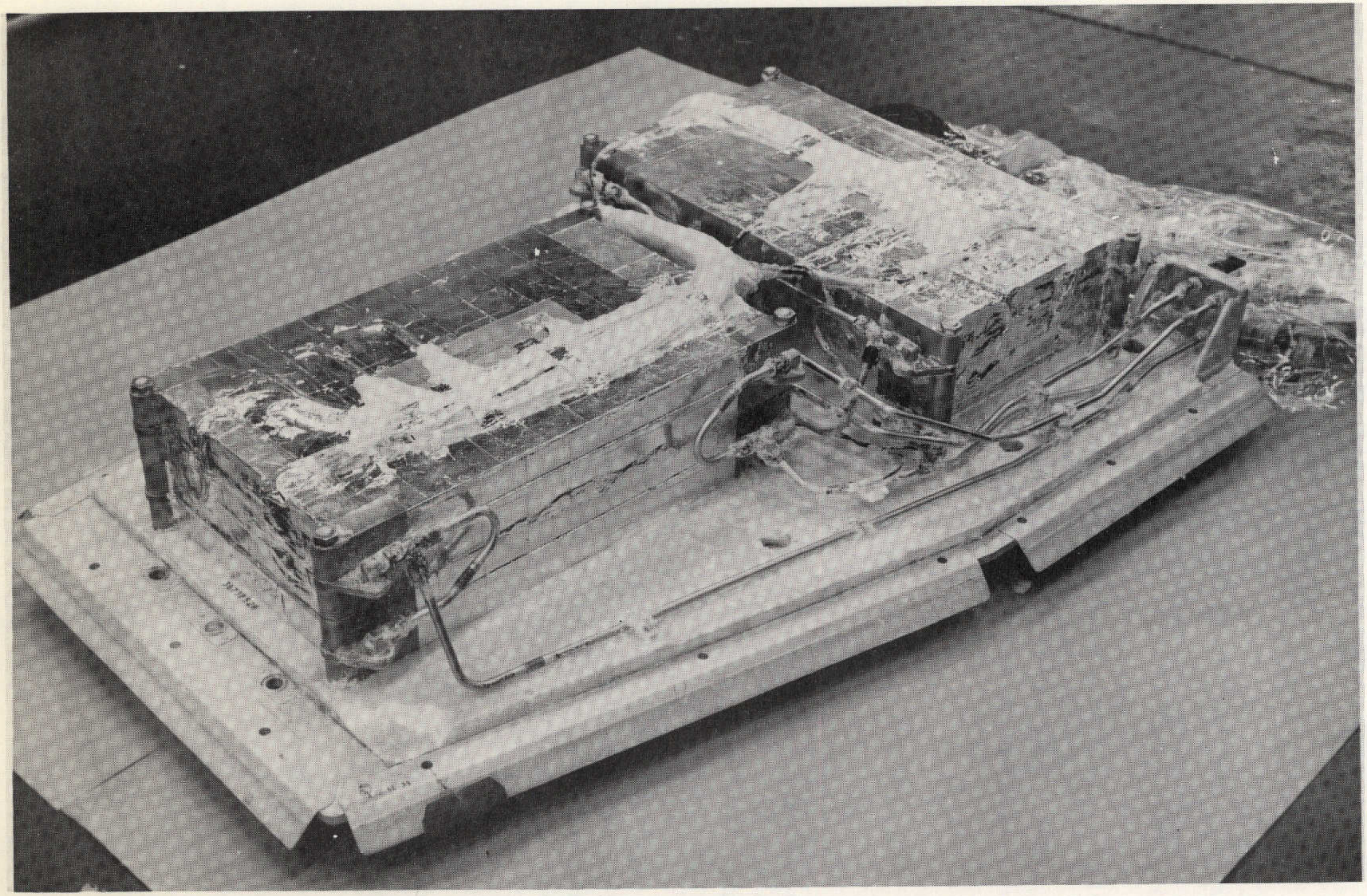

Figure 35. Original Skylab Radiator Loop Thermal Capacitor.

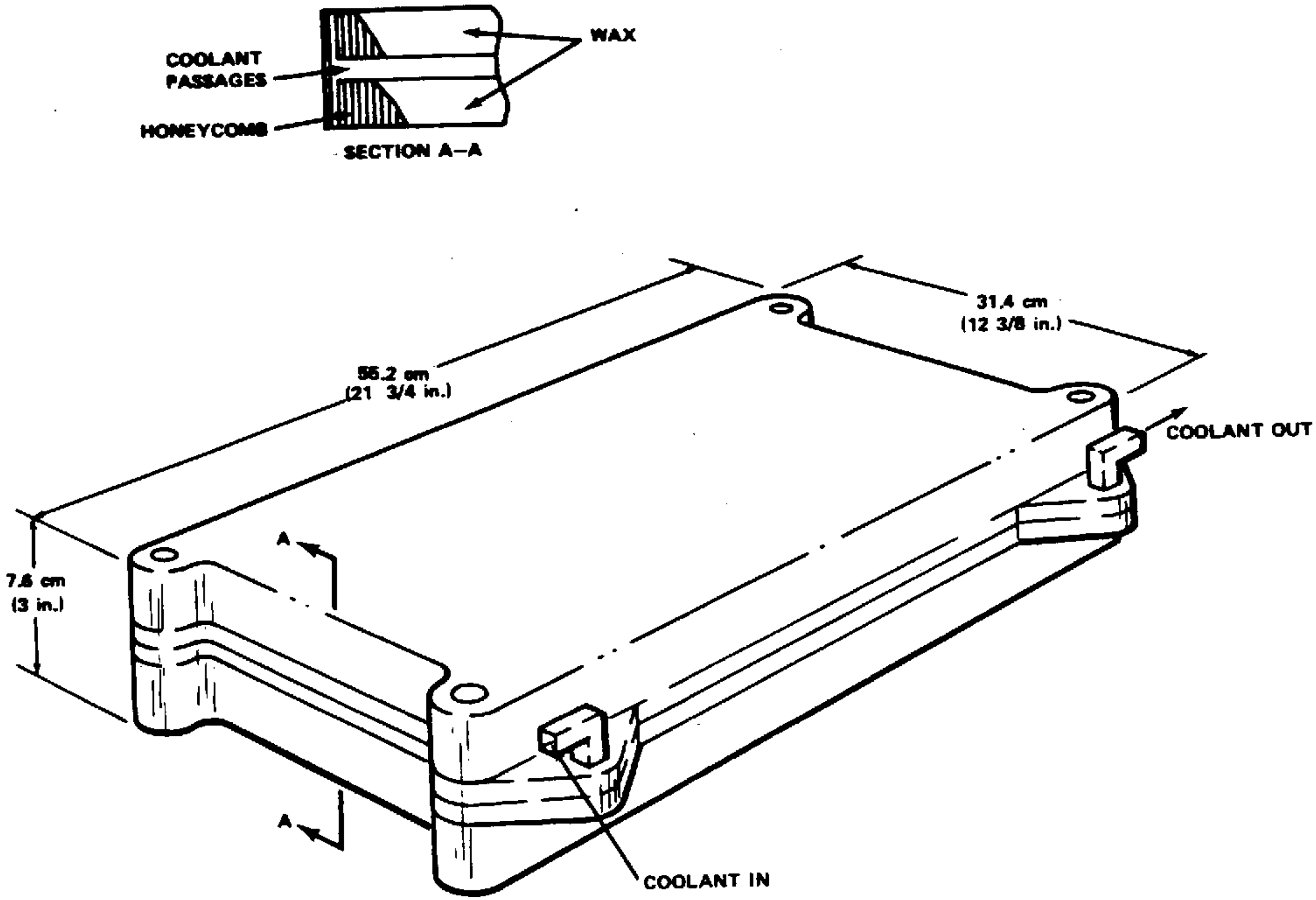

Figure 36. Redesigned Skylab Radiator Loop Thermal Capacitor.

COLD PLATE
(Saturn/Apollo Program – IU)

Vendor	Avco Corporation, Nashville, Tennessee
Vendor P.N.	2-10059-501
Usability	Little requalification test required; however, performance test required with new media. (See number M17 in Figure 1.)

DESCRIPTION

This unit (Fig. 37) was selected for baseline design. It contains a 5×5 cm grid pattern of threaded mounting holes for mounting components up to ≈ 90.72 kg. Basic design could be modified to reduce weight by removing honeycomb backup structure. Reconfiguration of coolant passages to reroute flow paths could readily be accomplished during manufacturing if required to handle special thermal cases. The unit weighs 14.5 kg.

Figure 38 is a cutaway view of the unit. Table 7 is a comparison of data for application of the unit in the IU and in Spacelab.

TABLE 7. COMPARISON OF ORIGINAL (SATURN/APOLLO IU) AND SPACELAB DESIGN REQUIREMENTS FOR THE COLD PLATE[a]

Parameter	Original Application	Spacelab Application
Medium	60/40 methanol/water	Freon 21
Pressure	344.75×10^3 N/m^2 gage operating 689.5×10^3 N/m^2 gage proof 1379×10^3 N/m^2 gage proof No spec. exists on vacuum filling coolant passages	1379×10^3 N/m^2 gage operating. Tests have shown coldplate burst pressure is well above 2413×10^3 N/m^2 gage
Flow, ΔP	41.4×10^3 N/m^2 max at 0.0252 kg/sec of M/W	ΔP and flow will be a function of application
Heat Removal	Remove 10 W per instrument mounting boss in any arrangement of inputs totaling 420 watts. Maximum temperature of any instrument boss is 26.6°C at 10 W with a 15.5°C coolant inlet temperature	Heat removal a function of flow rate, medium, and allowable temperatures at instrument mounting boss/coldplate interface
Temperature	15.5°C supply temperature	4.4 to 48.8°C supply temperature

a. Plate can be configured during manufacture to allow different mounting configurations. Honeycomb backing can be deleted without harming plate thermal properties.

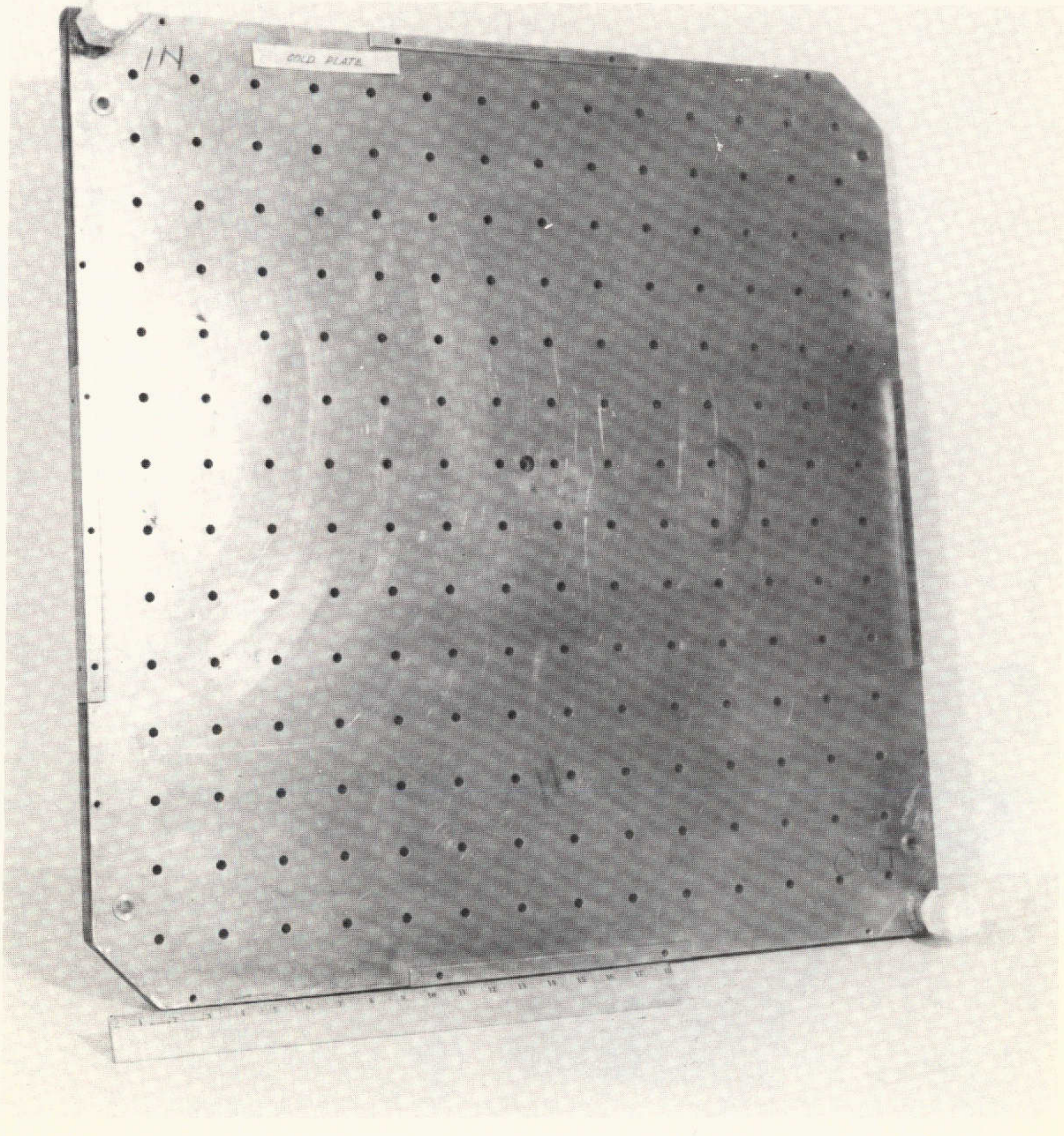

Figure 37. Cold Plate.

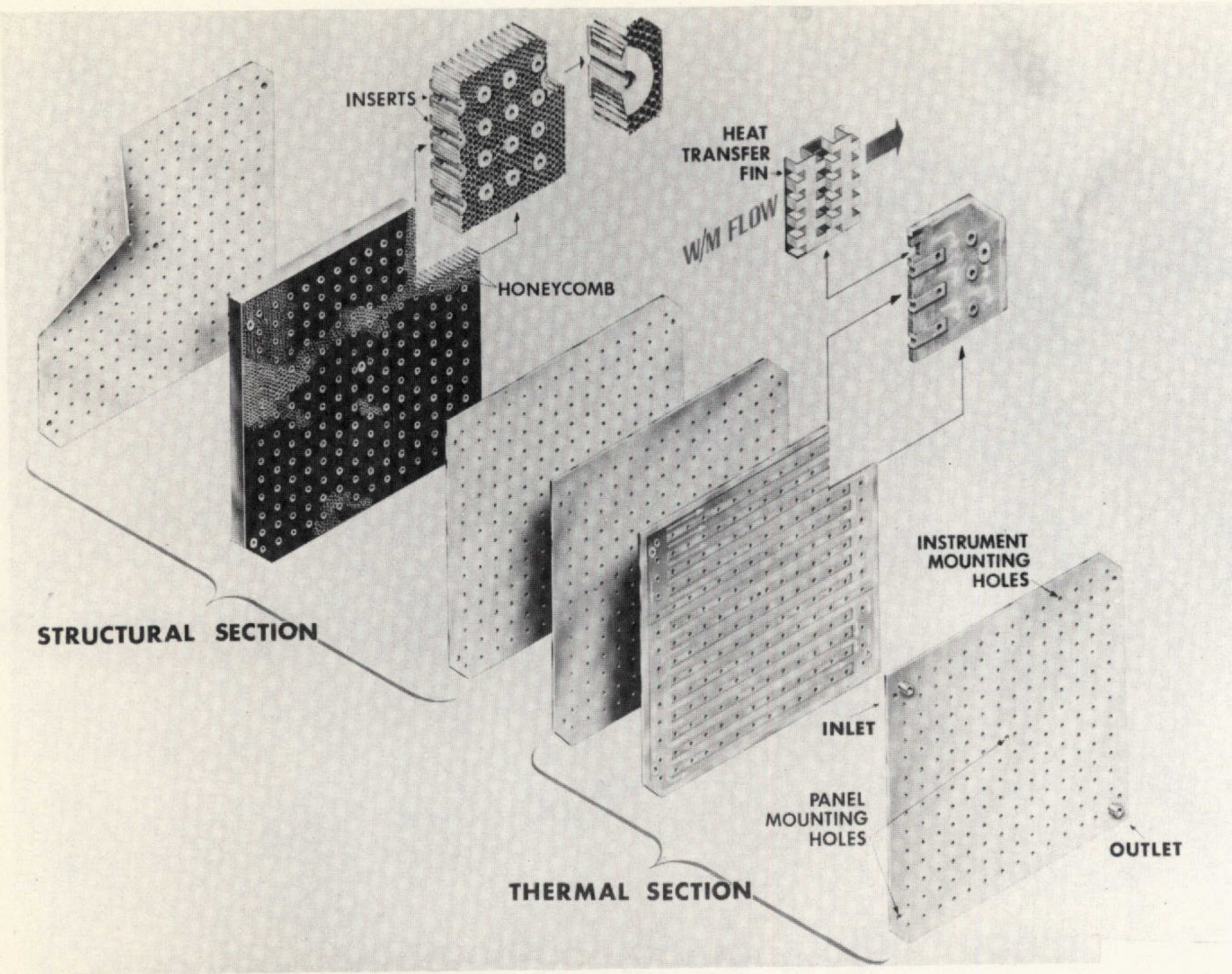

Figure 38. Cutaway view of Cold Plate.

TEMPERATURE CONTROL VALVE
(Skylab Program)

Vendor	Pyrodyne Division of Wahl Corporation, Los Angeles, California
Vendor P.N.	9674 (Redesign required to achieve proper temperature set point and ΔP)
Usability	A continued Phase B study will drop this valve in favor of a bank of bypass solenoid valves (provided temperature control band could be satisfied). Valves of this type experienced hang-up problems during the flight of Skylab. A similar valve concept in another Skylab subsystem was deleted from system prior to flight (due to development problems). The valve is basically simple but very contamination-sensitive. Additional basic development to make valve less failure sensitive is required. A procurement action was initiated by MSFC to buy a valve for development work (it was cancelled due to the European Spacelab agreement). (See numbers M9 and M14 in Figure 1.)

DESCRIPTION

The mix coolant temperature (from hot and cold inlet ports) at the valve outlet is controlled by the expansion of a "wax" capsule (thermal actuator) moving the flow control poppet. The valve is shown in Figure 39. A cross section of the valve is shown in Figure 40 (note that fitting design is not consistent with photo). The thermal actuator is filled with a thermal working fluid and is a sealed unit with stainless steel bellows. The dry weight of the valve is 1.36 kg.

A design specification summary of the temperature mixing valve is given in Table 8. The third column describes changes in parameters for potential Spacelab application.

TABLE 8. COMPARISON OF ORIGINAL (SKYLAB) AND SPACELAB DESIGN REQUIREMENTS FOR THE TEMPERATURE CONTROL VALVE

Parameter	Original Application	Spacelab Application
Medium	80/20 methanol/water with He and GN_2 purge	Freon 21
Pressure	344.75×10^3 N/m^2 gage operating 517.13×10^3 N/m^2 gage proof 861.88×10^3 N/m^2 gage burst	1379×10^3 N/m^2 gage operating
Flow and ΔP	0.113 kg/sec M/W at 27.58×10^3 N/m^2 max ΔP for full open cold port flow, 13.79×10^3 N/m^2 max ΔP for full open hot port flow	0.252 kg/sec of R21
Life	50 000 cycles	
Temperature Control	Mix temperature band is 10 ± 1.1°C at valve outlet with hot port inlet varying from 8.8 to 12.7°C and cold port inlet varying from -73.3 to 8.8°C at a 1.8°C/minute rate of temperature change for both inlet ports	Mix temperature band is 1.6 to 6.1°C at valve outlet with hot port inlet varying from 10 to 37.7°C and cold port inlet varying from -73.3 to 1.6°C
Electrical	N/A	N/A

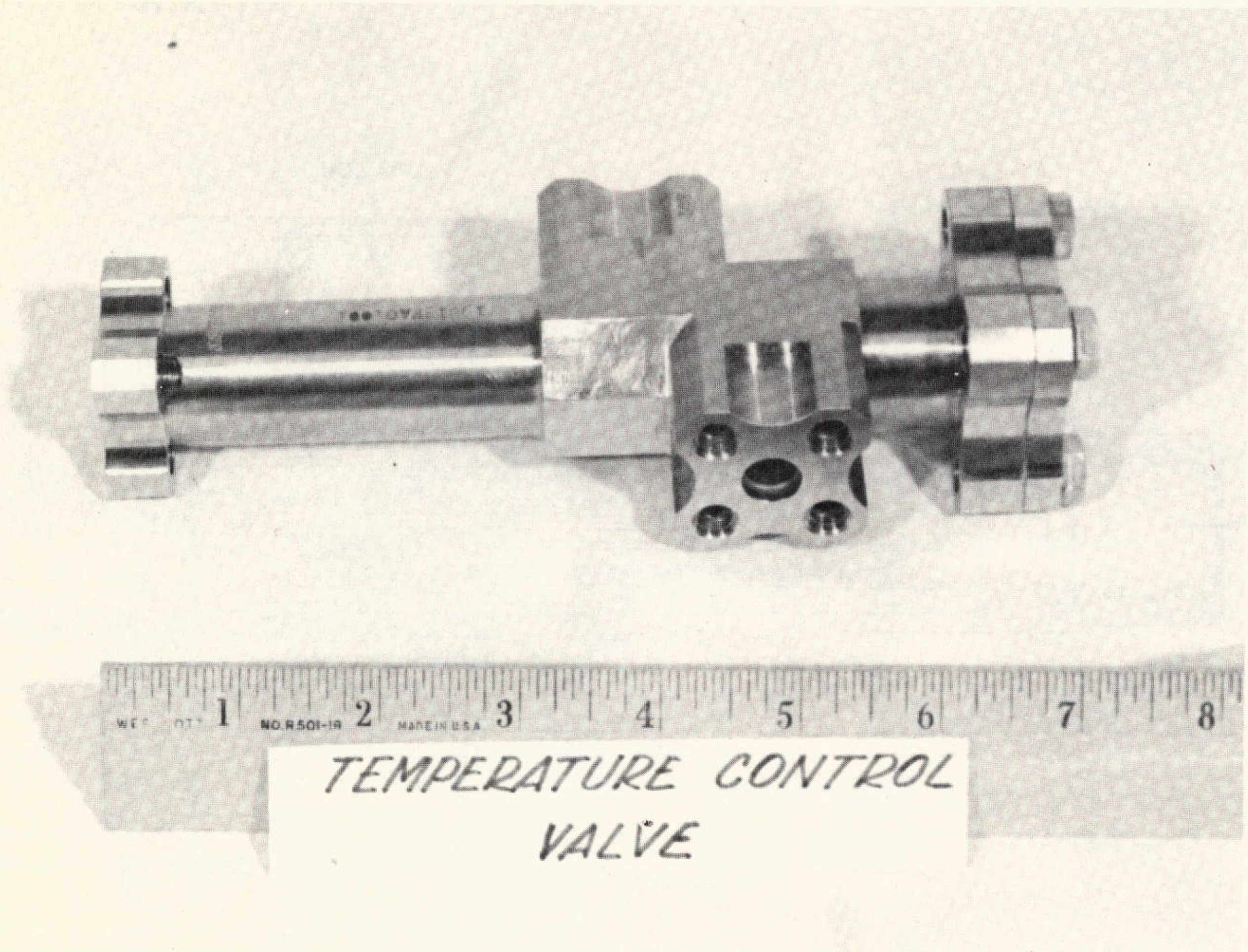

Figure 39. Temperature Control Valve.

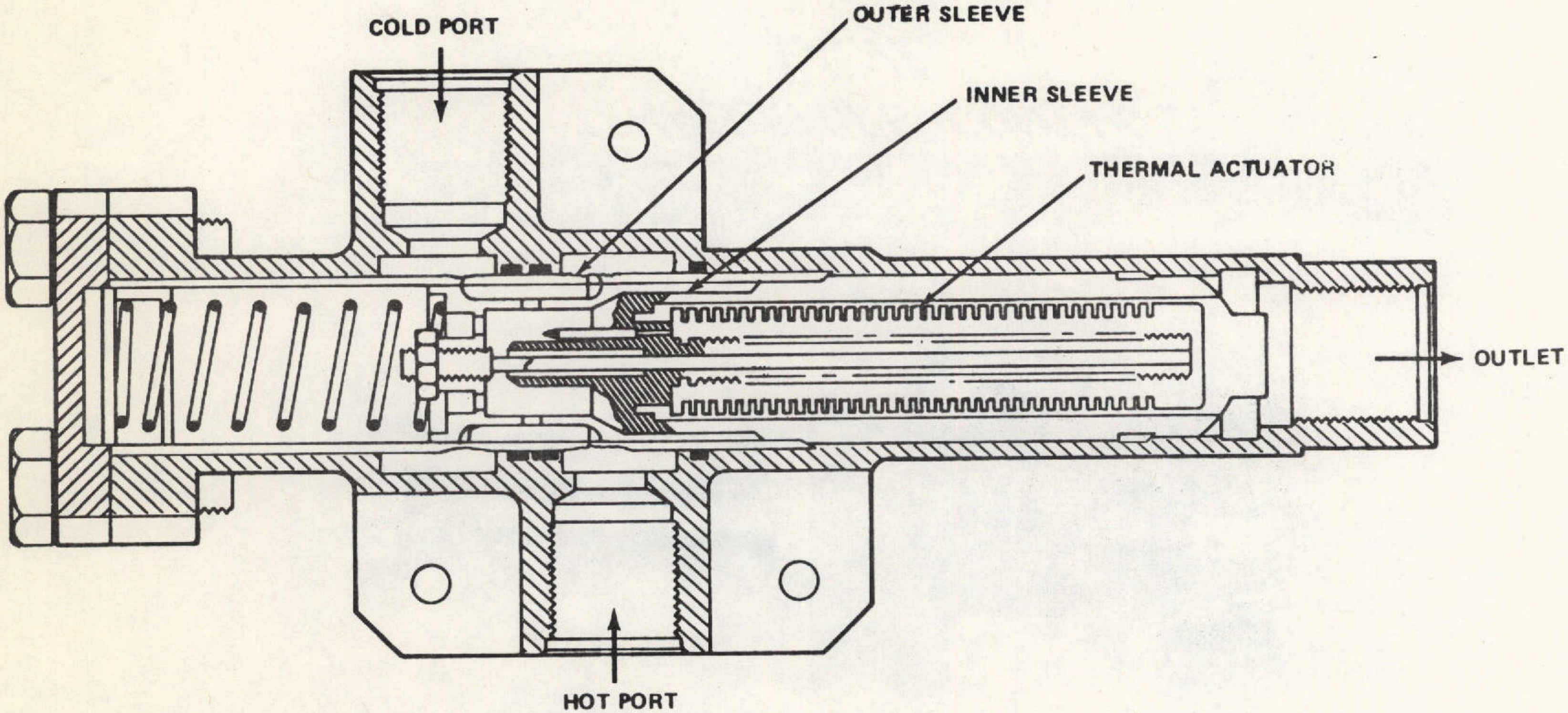

Figure 40. Cross-sectional view of the Temperature Control Valve.

SOLENOID VALVE

Vendor	Marotta Valve Corporation, Boonton, New Jersey
Vendor P.N.	Marotta P.N. 232624
Usability	Recommended for use on Spacelab for handling air, water, condensate, and GN_2.

DESCRIPTION

The valve shown in Figure 41 is a typical three-port valve and weighs about 0.91 kg. The weight of a typical two-port valve is about 0.68 kg. A group of three-port valves could also be used for controlling coolant loop flow to the cabin heat exchanger to control cabin air temperature.

Table 9 is a comparison of Saturn IU and Spacelab application of design requirements for a 0.68-kg, two-port, two-position solenoid valve with position switches. This valve was originally used in the Saturn IU Program to control the water feed to the sublimator.

TABLE 9. COMPARISON OF ORIGINAL (SATURN IU) AND SPACELAB DESIGN REQUIREMENTS FOR THE SOLENOID VALVE

Parameter	Original Application	Spacelab Application
Medium	Water, air, GN_2	Water, condensate, air
Internal Pressure	41.37×10^3 N/m^2 gage operating 62.05×10^3 N/m^2 gage proof 103.42×10^3 N/m^2 gage burst	$\approx 117.21 \times 10^3$ N/m^2 gage operating for water system application $\approx 34.48 \times 10^3$ N/m^2 vacuum below Lab cabin for air and condensate application
Operating Differential Pressure Across Poppet	The N. C. valve shall be able to open with 0.0 to 41.37 N/m^2 across poppet	$\approx 241.32 \times 10^3$ N/m^2 across valve poppet when valve is closed for water system application $\approx 117.21 \times 10^3$ N/m^2 across valve poppet when valve is closed for air and condensate application
Flow and ΔP	ΔP not exceed 1.03×10^3 N/m^2 at a water flow of 3.91×10^{-3} kg/sec	
Power Voltage	1.5 A at 24 Vdc and 19.9°C 24 to 30 Vdc normal operating range; minimum pull-in voltage is 18 Vdc, maximum drop-out voltage is 5.0 Vdc	
Outputs	A single pole double throw switch position indicator	
Life	250 cycles minimum	

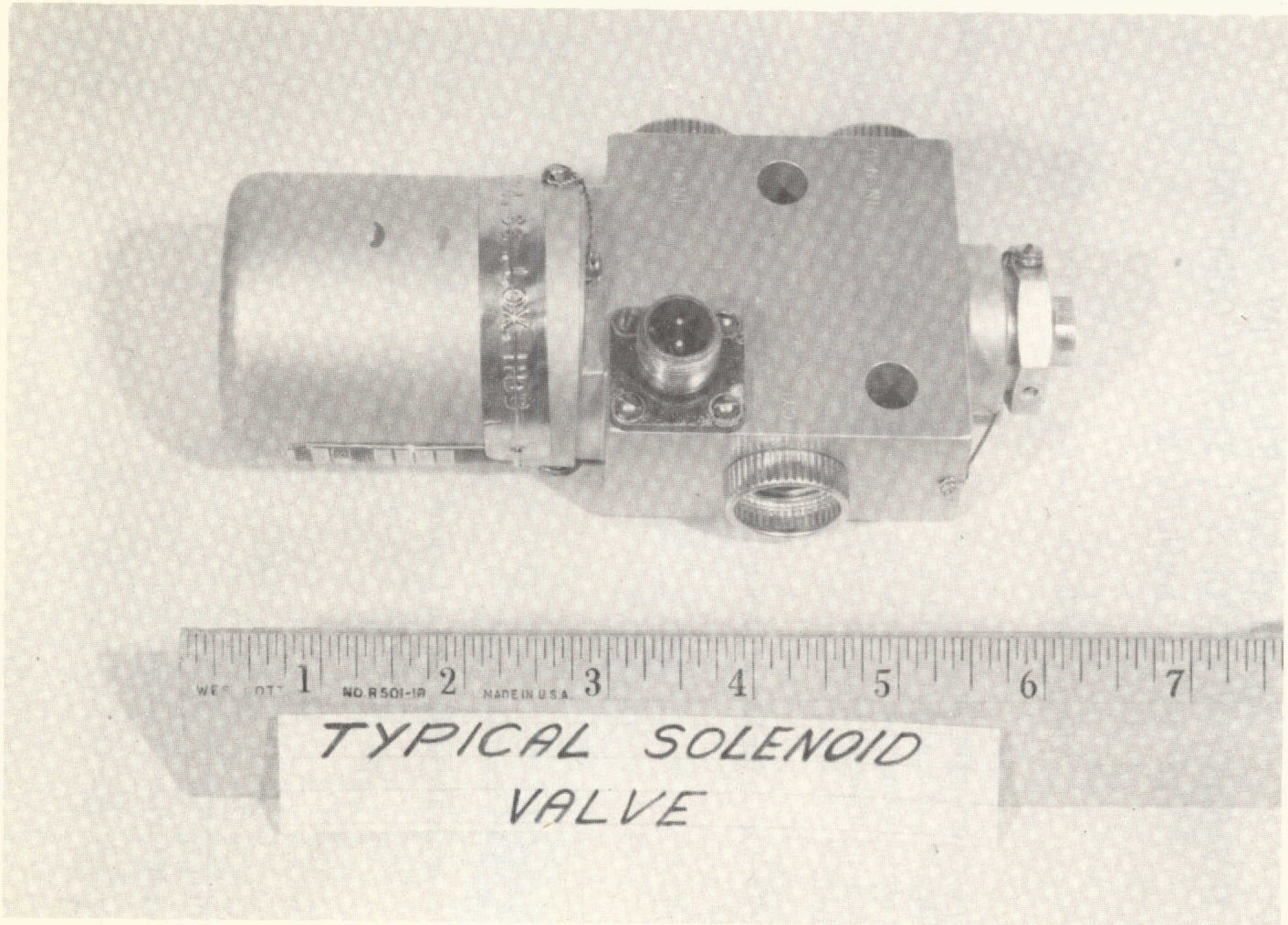

Figure 41. Solenoid Valve.

APPROVAL

SPACELAB PHASE B STUDY ENVIRONMENTAL CONTROL SYSTEM COMPONENT HANDBOOK

By R. A. Burns and A. J. Ignatonis

The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

This document has also been reviewed and approved for technical accuracy.

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